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AIR POLLUTION EPISODE EMERGENCY ACTION PLANNING MANUAL

TRW SYSTEMS GROUP, WASHINGTON, D.C.

PREPARED FOR
NATIONAL AIR POLLUTION CONTROL ADMINISTRATION
WASHINGTON, D.C.

15 NOVEMBER 1968

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Air Pollution Episode Emergency Action Planning Manual

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Public Health Service
National Air Pollution Control Administration
Washington, D.C.

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This manual is a guide for air quality program planners responsible for the design and implementation of episode avoidance actions. An episode is defined as the occurrence of stagnant air masses during which air pollutants accumulate, so that the population is exposed to higher-than-normal concentrations of the contaminants. The planning steps necessary to forestall the adverse effects of air pollution episodes are described. The manual is divided into three main parts, dealing with (1) emergency action plans, (2) problem definition, and (3) technical discussion. It covers both simple and more advanced technological procedures.

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FOREWORD

This Air Pollution Episode Emergency Action Planning Manual was prepared for the National Air Pollution Control Administration of the Public Health Service, U. S. Department of Health, Education and Welfare, by TRW Systems Group under Contract No. 10571.004.

This effort has been performed primarily by Resources Research, Inc., a sibsidiary of TRW Systems Group and has been directed by Dr. Harrison R. Hickey of RRI. Emphasis has been placed on what is currently being done at regional, state and large-city levels. Future efforts to be performed in Phase II will include the accidental episode situation.

Listed below are some of the NAPCA and regional air pollution personnel who were generous of their time and experience in helping to compile this Manual.

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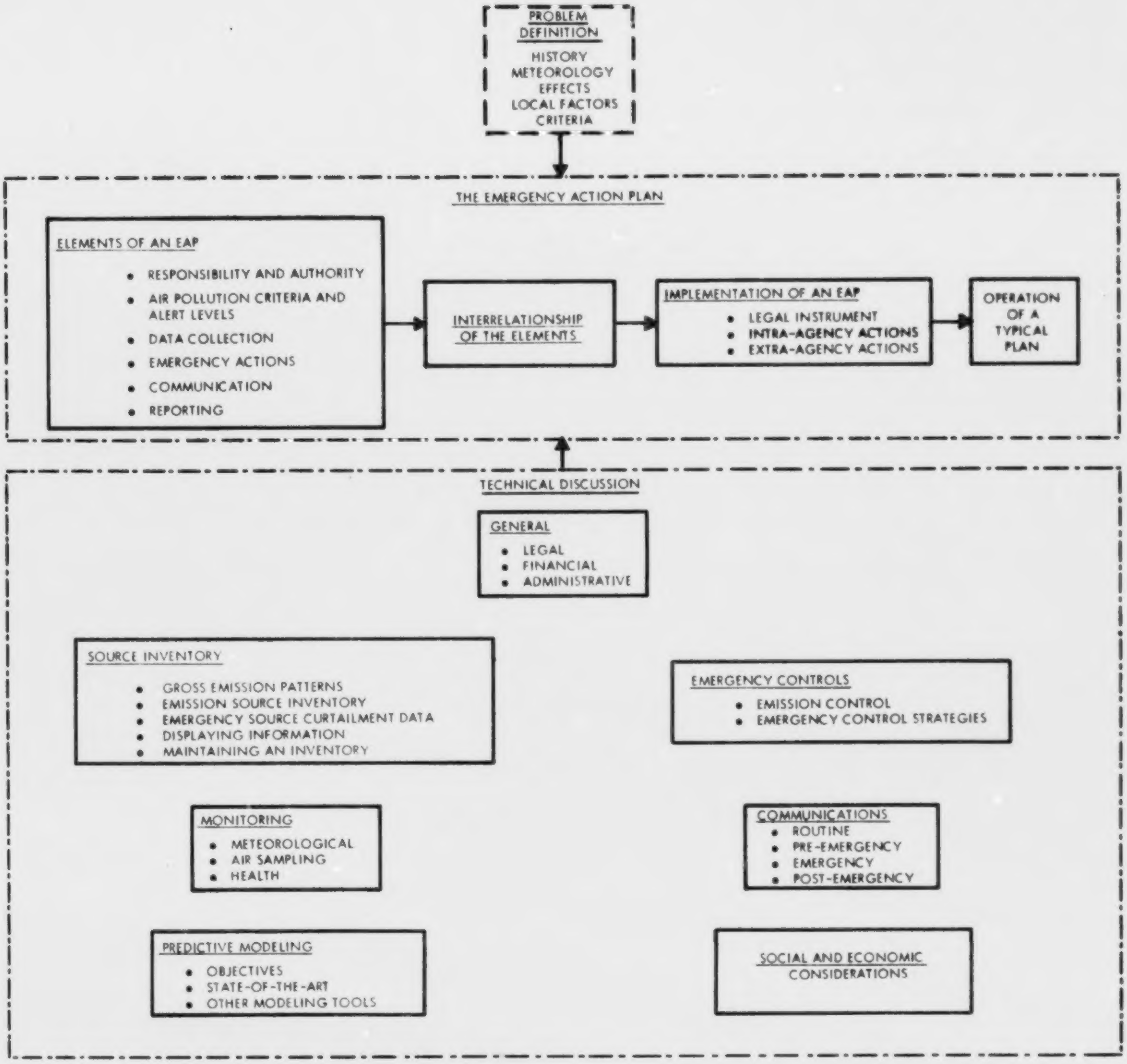
PROBLEM DEFINITION
HISTORY
METEOROLOGY
EFFECTS
LOCAL FACTORS
CRITERIA
THE EMERGENCY ACTION PLAN
ELEMENTS OF AN EAP
• RESPONSIBILITY AND AUTHORITY
• AIR POLLUTION CRITERIA AND ALERT LEVELS
• DATA COLLECTION
• EMERGENCY ACTIONS
• COMMUNICATION
• REPORTING
INTERRELATIONSHIP OF THE ELEMENTS
IMPLEMENTATION OF AN EAP
• LEGAL INSTRUMENT
• INTRA-AGENCY ACTIONS
• EXTRA-AGENCY ACTIONS
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GENERAL
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• GROSS EMISSION PATTERNS
• EMISSION SOURCE INVENTORY
• EMERGENCY SOURCE CURTAILMENT DATA
• DISPLAYING INFORMATION
• MAINTAINING AN INVENTORY
EMERGENCY CONTROLS
• EMISSION CONTROL
• EMERGENCY CONTROL STRATEGIES
MONITORING
• METEOROLOGICAL
• AIR SAMPLING
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COMMUNICATIONS
• ROUTINE
• PRE-EMERGENCY
• EMERGENCY
• POST-EMERGENCY
PREDICTIVE MODELING
• OBJECTIVES
• STATE-OF-THE-ART
• OTHER MODELING TOOLS
SOCIAL AND ECONOMIC CONSIDERATIONS

1.0 INTRODUCTION

1.1 OBJECTIVE

This manual is a guide for air quality program planners responsible for the design and implementation of episode avoidance actions. An episode is defined as the occurrence of stagnant air masses during which air pollutants accumulate, so that the population is exposed to higher-than-normal concentrations of the contaminants.

1.2 SCOPE

The Manual describes the planning steps necessary to forestall the adverse effects of air pollution episodes. Different regions have varying legal and administrative frameworks, as well as different meteorological, topographical and emission source characteristics. There are common elements, however, such as the need for knowledge of emission sources, an understanding of the behavior and conditions of the atmosphere, and the development of action plans for recognizing and coping with potentially severe episodes.

While essentially the same pollutants must be considered for episode control as for long-range or chronic control, and the Manual therefore could cover the enormous spectrum of total air quality problem areas, some practical limitations are set:

(a) The Manual emphasizes episode control; items not specifically concerned with this objective have been deemphasized.

(b) "Accidental episodes," such as emergencies resulting from the rupture of chemical vessels or transport lines, are not considered.

(c) Human health and welfare are the only direct effects considered; damage to vegetation and materials and indirect effects on the public welfare, for instance, are excluded.

(d) Detailed technical information needed in the practice of specialized technological or legal disciplines is excluded.

The Manual is divided into three main parts:

(a) Emergency Action Plans - Application and organization of the planning elements into a set of emergency action plans.

(b) Problem Definition - General background information on the subject matter.

(c) Technical Discussion - Details of the elements in an episode avoidance program.

The Manual covers both simple and more advanced technological procedures. Some control actions can be taken in any area; it is not absolutely essential that the most sophisticated inventory, monitoring and other procedures be available. Sophisticated techniques are desirable to ensure that actions are as well-founded as possible, and that they are planned and executed with the most benefit to society. Where problems exist but sophisticated techniques are not available, simpler tools such as gross inventory, manual sampling with telephone reporting and curtailment to reduce major emissions can be utilized as interim measures. However, planning of emergency actions for using these simpler tools may be only slightly less difficult than the planning for utilizing sophisticated techniques.

2.0 EMERGENCY ACTION PLAN

2.1 INTRODUCTION

A diagram of an Emergency Action Plan (EAP) is shown in Figure 2-1. A chart illustrating a method of displaying and selecting alternate emergency control actions is shown as Figure 2-2. An EAP will ordinarily be separate in some ways from air pollution management programs designed to control "chronic air pollution." Emergency Action Plans are required in anticipation of an immediate menace to public health and welfare. An air pollution episode is an unusual event; emergency actions may be appreciably more drastic than the normal pollution abatement activities of the control agency. Programs to improve normal ambient air quality may eventually eliminate the need for emergency procedures, but until then, definite preventive plans will be needed in episode-prone areas.

Control of the emissions of pollutants during potential episodes requires a large body of data on pollutant sources, dispersion of pollutants, possible control techniques, time-histories of pollution emission, information needs, etc. A checklist is shown as Table 2-1. This information must be collected and a Plan designed prior to the episodal event. Much but not all of the required information will be gathered for the purpose of "chronic" air quality control.

This section discusses the objectives, content, and operation of a "typical" Emergency Action Plan. The intent is not to spell out a universal model plan, but to provide a worklist of items which should be considered in designing and implementing a plan. Each area or region contains special conditions and limitations, and each planning item should be considered in the light of local requirements.

The necessity for careful and detailed preplanning cannot be overstressed; the time for reaction may be a matter of hours. Planning is necessary to assure that the required equipment, resources, personnel and procedures are available, and are ready to implement the desired communications and control actions.

Though a EAP is described above as a single document, there will actually be two plans: (1) a plan for activities within the air quality

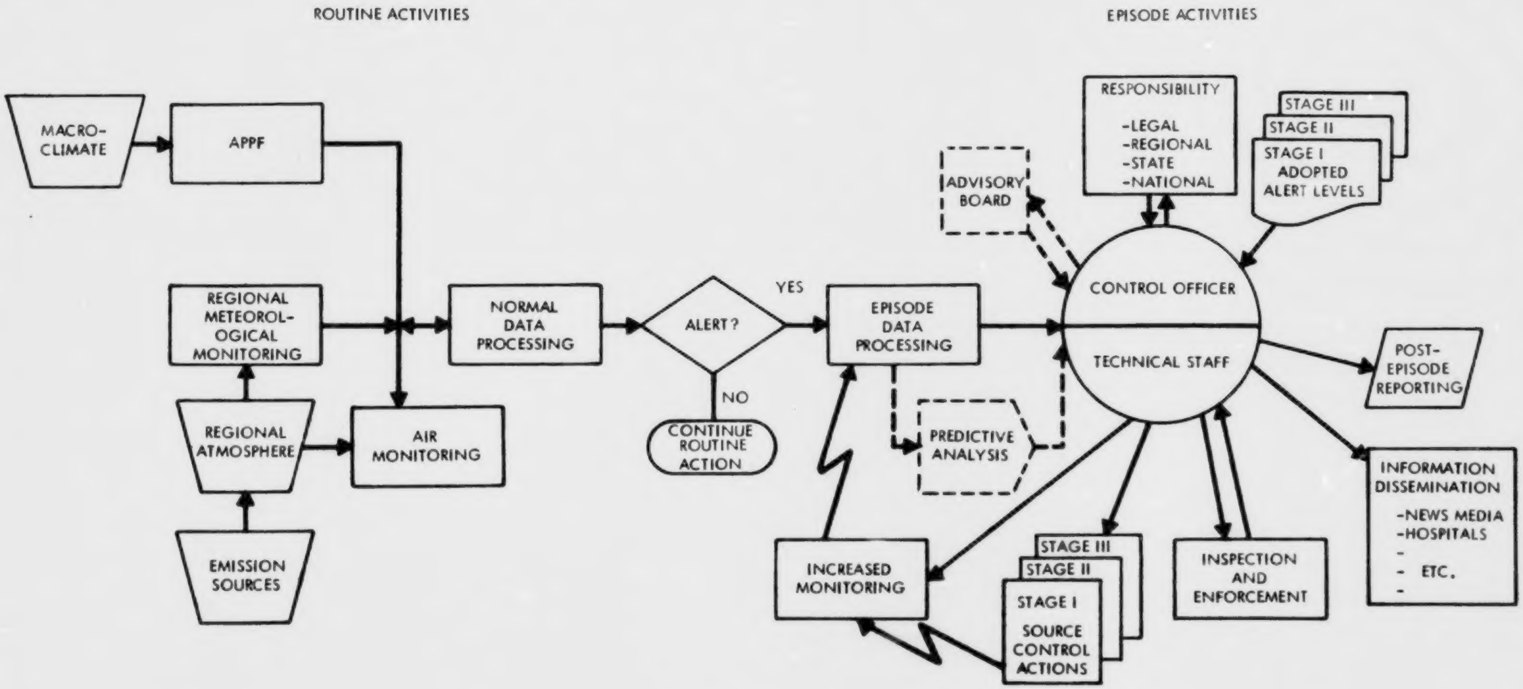

ROUTINE ACTIVITIES
EPISODE ACTIVITIES
MACRO-CLIMATE
APPF
REGIONAL METEOROL-OGICAL MONITORING
REGIONAL ATMOSPHERE
EMISSION SOURCES
AIR MONITORING
NORMAL DATA PROCESSING
ALERT?
YES
NO
CONTINUE ROUTINE ACTION
EPISODE DATA PROCESSING
PREDICTIVE ANALYSIS
ADVISORY BOARD
RESPONSIBILITY
-LEGAL
-REGIONAL
-STATE
-NATIONAL
STAGE III
STAGE II
STAGE I ADOPTED ALERT LEVELS
CONTROL OFFICER
TECHNICAL STAFF
POST-EPISODE REPORTING
INFORMATION DISSEMINATION
-NEWS MEDIA
-HOSPITALS
- ETC.
INSPECTION AND ENFORCEMENT
STAGE III
STAGE II
STAGE I SOURCE CONTROL ACTIONS
INCREASED MONITORING

Figure 2-1. Emergency Action Plan (EAP)

CATEGORY	SOURCE TYPE	CURTAILMENT PLAN DESIRABLE (f)			SWITCH TO SULFUR FUEL			LOAD SHIFTING			LIMIT CLEANING AND START UP OPERATIONS			PLANNED PROCESS MODIFICATION			PARTIAL SHUTDOWN			START NO NEW BATCHES			REDUCE TO STANDBY			SHUTDOWN OR BAN			SELECTIVE SHUTDOWN			INCREASE ACTIVITY		
	ALERT LEVEL	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
POWER GENERATION		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨		▨	▨																		
OTHER FUEL BURNING SOURCES	INDUSTRIAL	▨	▨	▨	▨	▨	▨				▨	▨		▨	▨	▨		▨	▨		▨	▨		▨	▨			▨						
	COMMERCIAL	▨	▨	▨	▨	▨					▨	▨						▨	▨		▨	▨		▨	▨			▨						
	PROCESSING	▨	▨	▨	▨	▨					▨	▨						▨	▨		▨	▨		▨	▨			▨						
	RESIDENTIAL				▨	▨	▨				▨	▨	▨					▨	▨															
INCINERATION	MUNICIPAL	▨	▨	▨													▨							▨				▨						
	COMMERCIAL	▨	▨	▨													▨							▨				▨						
	RESIDENTIAL																									▨	▨	▨						
	OPEN																									▨	▨	▨						
MANUFACTURING(a)	CONTINUOUS	▨	▨	▨	▨	▨	▨				▨	▨	▨	▨	▨	▨		▨	▨						▨			▨						
	BATCH PROCESS	▨	▨	▨	▨	▨	▨				▨	▨	▨	▨	▨	▨					▨	▨		▨	▨			▨						
COMMERCIAL(b)	ENTERTAINMENT	▨	▨	▨	▨	▨					▨	▨						▨										▨						
	OFFICE WORK	▨	▨	▨	▨	▨					▨	▨						▨										▨						
	BUSINESS	▨	▨	▨	▨	▨					▨	▨						▨										▨						
PROCESSING(c)		▨	▨	▨	▨	▨					▨	▨						▨										▨						
AGRICULTURAL	PROCESSING(d)	▨	▨	▨	▨	▨					▨	▨		▨	▨	▨		▨	▨						▨			▨						
	FIELD OPERATIONS(e)																						▨	▨	▨	▨	▨	▨						
GOVERNMENTAL	SCHOOLS																									▨	▨	▨						
	GENERAL OFFICE																									▨	▨	▨						
	PUBLIC SAFETY																															▨	▨	▨
CONSTRUCTION																					▨	▨					▨	▨						
ESSENTIAL FACILITIES	FOOD DISTRIBUTION																														▨			
	HOSPITAL & MEDICAL																															▨	▨	▨
	PHARMACIES																																	
	PUBLIC SAFETY																															▨	▨	▨
	COMMUNICATIONS																															▨	▨	▨
	NEWS MEDIA																															▨	▨	▨

(a) Manufacturing includes metallurgical, chemical, petroleum, mineral, paper, mining, etc.

(b) Commercial includes financial, stores, entertainment, offices, services, wholesalers, restaurants, etc.

(c) Processing includes laundries, dry cleaners, garages, service stations, food preparation, etc.

(d) Agricultural processing includes ginning, milling, feed and feed supplement processing.

(e) Agricultural field operations include spraying, dusting, field burning, grading, plowing.

(f) Size and emissions determine which commercial, processing, and agricultural plants must file plans.

Figure 2-2. Alternate Emergency Control Actions

TABLE 2-1

STEPS IN PREPARING AN EMERGENCY ACTION PLAN

A. RESPONSIBILITY AND AUTHORITY

1. Determine the boundaries of the control region, and explore cooperative relations with adjoining areas; decide on interagency strategies in calling alerts; examine special boundary problems.
2. Establish the lines of authority for emergency actions, which may be different at each alert state (only, the Governor, may call a "third Alert" in some instances).
3. Determine whether an advisory emergency committee will be part of the plan; each member should have an alternate.
4. Establish the legal authority to exercise emergency control actions, including civil or criminal law enforcement tools.
5. Obtain the approval of the mayor, governor, and NAPCA (if desired) for the structure of authority.

B. ALERT CRITERIA

1. Assemble the necessary emission and air sampling background information to define the local physical problem.
2. Establish a committee to review and recommend alert criteria; the committee should include the disciplines of medicine, meteorology, air pollution engineering, government, law and public safety (police).
3. Review the criteria which have been adopted in other similar areas, if any; prepare arguments for revising them or developing new criteria, considering episode-proneness, local air quality status and controllable elements.
4. Establish the responsibility and procedures for calling alerts.
5. Plan for annual review of the alert criteria, or special review following a major episode.

C. BACKGROUND INFORMATION

1. Develop emission inventory data, using records of other agencies (Urban Planning, etc) where possible; develop means for updating periodically.
2. Define the measurement systems necessary to recognize alert criteria conditions, including measurement methods, number of sampling stations, and averaging times; establish meteorological data linkages.
3. Define the physical data to be monitored routinely, and intensified monitoring (meteorological and air sampling) during potential episodes.
4. Establish procedures and systems for processing and reviewing data - during potential episodes, including meteorological predictions.
5. Give local medical interests the opportunity to couple exposure experience with health effects by preplanning cooperative studies.
6. Develop decision-making "software"; if reliance is placed on committee decisions, detail the information to be supplied the committee.
7. Procure enough air sampling and meteorological data to define concentrations of pollution under several dispersion conditions. Use judgement on models to estimate frequencies of various alert levels.

D. EMERGENCY SOURCE CURTAILMENT ACTIONS

1. For each alert level, establish the "canned" or variable actions to be taken for:
    - a. power generation,
    - b. other industrial sources, by class and size,
    - c. commercial sources, by class and size
    - d. incineration: municipal, commercial, construction, and residential,
    - e. motor vehicles,
    - f. general business activity curtailment (for "high" alerts, essential activities such as medical services may be detailed, or non-essential activities may be spelled out - both systems are used).
2. Establish which actions are voluntary and which are mandatory.
3. Establish the requirement for "shutdown" plans - mandatory submittal or on-call review.
4. Define inspection and enforcement procedures, including personnel and equipment requirements.
5. Develop recommendations to local medical groups on advising their patients.

E. COMMUNICATIONS

1. Establish a direct communications link (24 hours/day) with major emission sources; establish contacts and alternates for each.
2. Determine information desired by stateand federal authorities, and form in which it is desired.
3. Design the local information system, including flow-diagram showing police, civil defense, public safety, and private communication links, and coordinate with each to define their roles. (Police and taxicab radios have served as emergency communication networks, for instance.)
4. Prepare sample news releases; consult with other control agencies experienced in problems of dealing with the public in these matters.

F. REPORTING

1. Determine whether legal documentation of data is required; this may be simply the APPF bulletin plus local sampling station measurements.
2. Prepare an outline of points to be covered in a summary report of the event for news media.
3. Prepare an outline for a technical summary report, to include a record of the times of emission curtailment actions, sampling stationshistories, and observed effects, as well as the climatology of the event.
4. Prepare an outline of a report on control agency activities during the potential episode, to highlight possible improvements.

control agency itself, and (2) a plan for the interactions between the control agency and all others (other government agencies, industries generating emissions, news media, etc.). The development of these plans or a single integrated plan involves the preparatory steps in Table 2-1.

An example of emergency control actions which might be taken is shown in Appendix J; this example is being considered by the State of New Jersey at the present time.

2.2 INTERRELATIONS OF THE EAP ELEMENTS

The Emergency Action Plan (EAP) is dynamic, involving the flow of information between different elements with appreciable interaction between the elements. This is shown schematically in Figure 2-3 for both routine and episode avoidance activities. The elements are connected to the agency by arrows, each of which represents a required communication link. The information flow into the agency comes from a number of sources, such as the current status of the atmosphere. Information is also required on pollutant emissions and on the availability of control actions. The control agency interprets the incoming information, using predictive models or judgment, and estimates the present and probable future status of the atmosphere. This information is compared with the air quality criteria established in the EAP. At defined levels of pollutant exposure and expected persistence of meteorological conditions, the responsible control officer calls an alert.

Information now flows outward from the control agency as planned actions for control of emissions and information dissemination are executed. Typical communications at this point include:

(a) Notification of requirements for increased air monitoring, meteorological measurements, and inspection,

(b) Notification of the public through news media, interested public officials and public agencies of the present status,

(c) Notification of affected pollutant sources of the requirement to reduce emissions in accordance with the EAP.

As the pollution sources reduce emissions into the atmosphere, the effects are detected by the air monitoring system and depending on local conditions, pollutant levels either hold, continue to rise, or decrease. If the pollutant levels rise (considering diurnal effects), it may be necessary to take more drastic control actions. Again the control agency uses the air pollution criteria established in the EAP as a measure of the actions to be taken. In the typical EAP there will be specified control actions for different alert levels.

A four-stage alert system is shown schematically in Figure 2-3 and typical control actions that might be taken for the different alert stages are illustrated in Figure 2-2 and are described in the hypothetical episode presented in Section 2.4.

2.3 IMPLEMENTATION OF AN EMERGENCY ACTION PLAN (EAP)

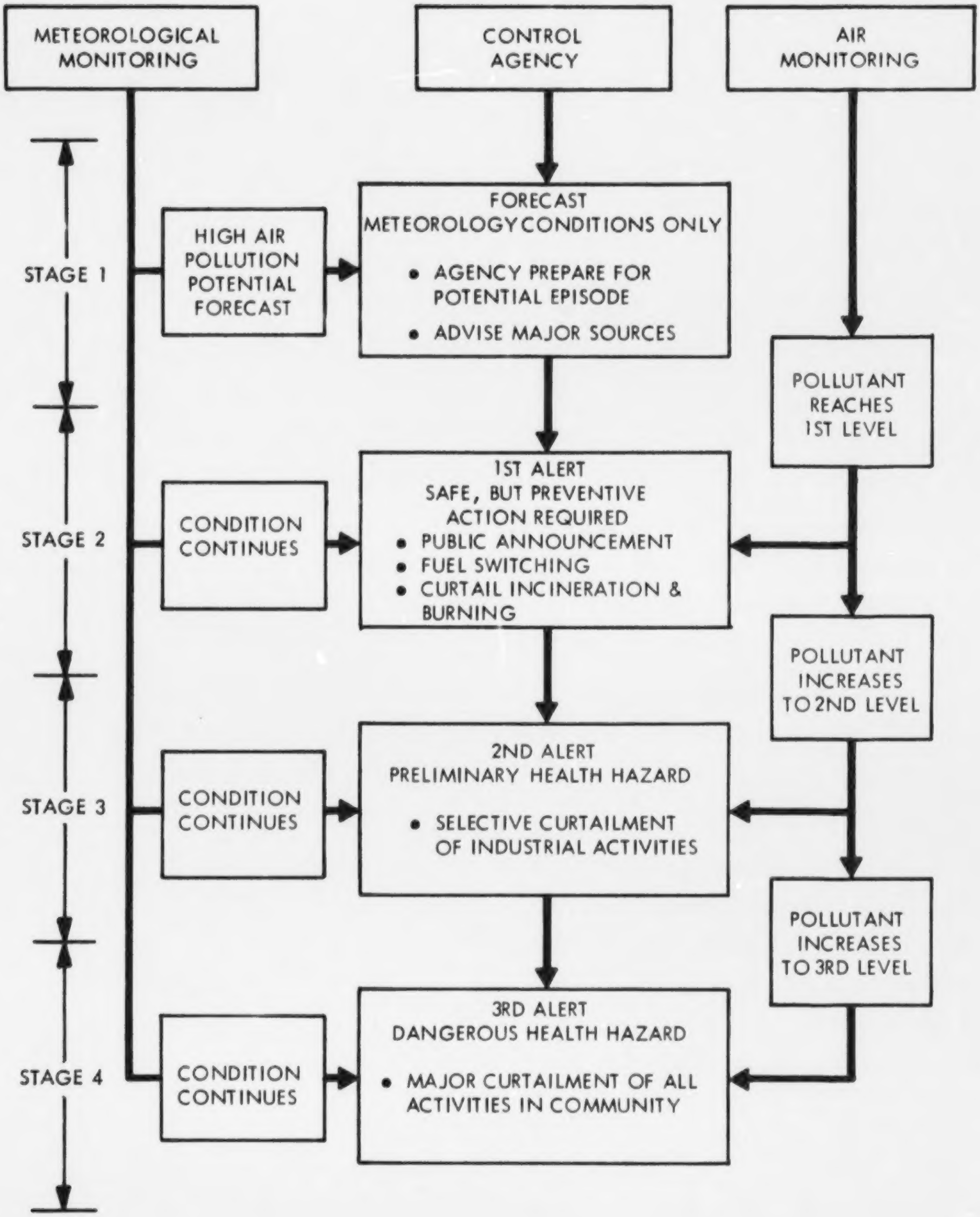
The previous sections discussed the elements of a formal EAP. Typically, the formulation of such a plan will be the result of advisory committees working closely with control agency personnel. The implementation of the EAP, once adopted, will in general be the sole responsibility of the control agency.

The first subsection below discusses briefly the necessity for a legal instrument. The later subsections will discuss those items both within and outside control agencies that must be considered in the implementation of the plan.

Each control agency will have different requirements, budgets and legal instruments. Therefore, it is impossible to cover all possibilities in a brief discussion, and the reader should relate his circumstances to the discussion with judgment. Familiarity with problems encountered by other similar agencies is a valuable source of practical information on plan implementation and communication. Each control agency will wish to tailor an EAP to its particular needs.

2.3.1 THE LEGAL INSTRUMENT

For immediate stages of "alerts," it is possible that voluntary cooperation by emitters of pollutants will produce good results. This depends on the nature of the problem. If a few major sources are to be



METEOROLOGICAL MONITORING
CONTROL AGENCY
AIR MONITORING
STAGE 1
HIGH AIR POLLUTION POTENTIAL FORECAST
FORECAST METEOROLOGY CONDITIONS ONLY
• AGENCY PREPARE FOR POTENTIAL EPISODE
• ADVISE MAJOR SOURCES
POLLUTANT REACHES 1ST LEVEL
STAGE 2
CONDITION CONTINUES
1ST ALERT SAFE, BUT PREVENTIVE ACTION REQUIRED
• PUBLIC ANNOUNCEMENT
• FUEL SWITCHING
• CURTAIL INCINERATION & BURNING
POLLUTANT INCREASES TO 2ND LEVEL
STAGE 3
CONDITION CONTINUES
2ND ALERT PRELIMINARY HEALTH HAZARD
• SELECTIVE CURTAILMENT OF INDUSTRIAL ACTIVITIES
POLLUTANT INCREASES TO 3RD LEVEL
STAGE 4
CONDITION CONTINUES
3RD ALERT DANGEROUS HEALTH HAZARD
• MAJOR CURTAILMENT OF ALL ACTIVITIES IN COMMUNITY

Figure 2-3. A Four-Stage Alert Sequence

controlled, voluntary action may be adequate. If the principal problem is automobile exhaust, it probably will not.

For "high" alerts, keyed to imminent and large-scale disaster, the legal instrument will be the authority of the governor to "declare a disaster." This may be in some cases the only emergency action control step anticipated. For less severe measures, the legal instrument will be a matter of local (perhaps state) law, and can assume a wide variety of forms. Information on legal considerations will be found in Section 4.2. Professional help in legal matters is an obvious need of the local or regional control agency.

2.3.2 INTRA-AGENCY CONTROL ACTIONS

In this section some typical actions for implementation of a plan within the control agency are described. Section 2.3.3 describes those actions that involve interfaces between the control agency and non-agency components. The basic intra-agency actions are (a) determine what resources are required during an episode (data, personnel, equipment and plans), (b) insure that they are available and ready for use, (c) apply the proper resources during a potential episode.

2.3.2.1 Personnel

The personnel requirements during an episode are more severe than those of a normal air management program. Continuous surveillance is highly desirable. A personnel plan should be drawn up defining the tasks and personnel requirements during an episode. In most cases it will be apparent that the regular shift arrangements will not be adequate and extended work days will be required. Arrangements for food should be made, and cots may be supplied for some staff members.

Automation tends to lessen personnel requirements during an episode, in addition to improving the quality and speed of data collection and analyses.

All personnel should be informed of their expected tasks and schedules before an episode. Vacations should be coordinated to insure adequate personnel at all times during the high-episode-potential season. Responsible alternates should be designated for all decision-making positions.

2.3.2.2 Data Collection

Avoidance of episodes requires that accurate air quality and meteorological information be available at all times for rapid decision making. Though it should not be considered an absolute requirement for an EAP, this is best accomplished by a computerized system in which air sampling and meteorological data are telemetered to the control center, processed by a computer and displayed. The major advantages of a computerized system are the capability to: (a) process large quantities of input data in a short time, (b) store large quantities of data with rapid retrieval, (c) process multivariable data, to conveniently display such data, (d) perform simulations using predictive models, and (e) lower the manpower requirement during an episode, once the computer is programmed.

Many public agencies presently employ a computer for accounting and engineering purposes; the computer in some cases is made available to the control agency for use during an episode on an emergency basis. An additional advantage cf this approach is the availability of trained computer-operations people to help with the peak personnel problem during the episode. The decision to use a borrowed computer or to buy or rent one should be based both on present and projected future requirements, namely:

(a) Availability of the computer for other control activities,

(b) Compatability with present and projected input, output, and display equipment,

(c) Versatility of the computer for, use in predictive modelling computation and display, and for nonepisode data bank storage,

(d) Ability to upgrade computer system in the future,

(e) Costs, both initial and future,

(f) Availability of trained computer personnel.

During an episode there is a requirement for near-real-time display of air quality data from a variety of locations. This is best accomplished with automated air sampling stations equipped with telemetering links to the control center. Those agencies initially selecting manual equipment because of budget limitations should consider the future possibilities for automation in selecting equipment.

Data may be acquired from extra-agency sources such as the Weather Bureau, continuous air monitoring program system, universities, and industries. After selecting the data source, the (CAMP) computer, and the input and display equipment, the computer must be programmed to perform the desired tasks. If data are to be processed manually, appreciable planning is necessary to insure that the required processed data will be available in time to assist the control agency with decisions. Dry runs actually simulating episode conditions will be useful for this.

2.3.2.3 Communication Plans

One key to efficient control action during an episode is good communications, both intra- and extra-agency. Within the agency a communication plan is required for:

(a) Personnel notification of alert status,

(b) Contacting of field personnel,

(c) Reporting of the results of inspections,

(d) Status reports to ex officio members of the agency, i.e., mayor, governor, etc.

Communications will be further discussed in the section on extra-agency activities and in Section 4. It is worth noting here that a good communications center should be equipped with emergency radio, phone, teletype and possibly intercom systems.

2.3.2.4 Emergency Control Action

Responsibilities of the control agency during an episode for direct emergency control action are primarily the identification of alert situations and:

(a) Communication of the alert situation to the affected party or parties,

(b) Inspection to insure compliance with required action,

(c) Enforcement actions against violators.

An internal agency plan should be drawn up in advance detailing the inspection requirements during an episode. Gathering evidence for enforcement actions against violators should be planned. During the episode the control officer typically will increase field inspection activities. Specific stack sampling tasks may also be specified.

2.3.3 EXTRA-AGENCY CONTROL ACTIONS

The primary concern in those actions during an episode involving interfaces between the control agency and extra-agency groups is the rapid two-way flow of information. Typical extra-agency activities are described below. The term "outside agency" is brief form for groups such as the Weather Bureau, neighboring control districts, industries, hospitals and the like, including emission sources.

2.3.3.1 Responsibility

The EAP should call out the expected interactions with outside agencies, officials and committees during a potential episode. It is the responsibility of each control agency to insure that actions by extra-agency groups are coordinated with the local control agency's plan of action.

2.3.3.2 Data Collection

In general the majority of the information required by the control officer will be generated within the agency itself. Some data may be provided by outside agencies, and the control agency will want to insure that such data are smoothly integrated with general data collection, processing and decision systems employed. This will involve coordination and planning prior to the potential episode.

The United States Weather Bureau is the outside agency of most importance during potential episodes. (Local meteorological data requirements are discussed in Section 4.4.1.) The control agency should establish its data requirements and communicate these to the Weather Bureau. (In some areas, special cooperative programs are now underway.) A joint plan of action should be prepared. Items to be considered in this plan include:

(a) Weather Bureau capabilities in air pollution potential forecasting (APPF)

(b) Communication of Weather Bureau information to the control agency,

(c) Responsibilities for information dissemination,

(d) Equipment or personnel required that must be supplied by or to the agency for a cooperative function.

The control agency will feed back to the Weather Bureau information on the status of the episode, key locations where air pollution appears to be rising and other information required to assist in the resolution of meteorological data. Special rawinsonde soundings for temperature gradients may be implemented. Helicopters may be used for obtaining both meteorological data and air samples, and their flight paths may be adjusted on the basis of observations at ground level stations.

Other agencies that may be sources of information during an episode include:

Neighboring Control Agencies

Provisions should be made for exchanging air pollution sampling data, meteorological data, alert status and planned actions with neighboring control agencies. This can be particularly important if there is a significant transfer of pollutants into or from adjoining areas, and if -- as will normally be the case -- the areas are served by the same TV stations and newspapers. In most cases coordination of alert actions will be desirable to avoid confusion.

Regional, State and Federal Control Agencies

Data may be collected by these agencies during an episode. Examples are the Continuous Air Monitoring Program and the National Air Sampling Network. These data should be integrated into the local system. The regional or state control agencies may also desire data from the local control agency.

Industrial Sources

Many private industries now have meteorological capabilities - often both wind speed and direction recording; some have air sampling capabilities as well. Often they will be willing to make at least the meteorological data available to the control agency. In some cases large emitters (for example, power generation plants) can provide up-to-date information on pollutant emission rates.

Public Safety Agencies

> The police can supply information on up-to-date and expected trends in automobile traffic as well as on compliance with visible source control requirements; their radios can serve as a supporting communications network. Public health agencies can provide information on hospital admissions and morbidity which might be useful in evaluating health effects during and following an extended episode.

These outside agencies must be made aware of the data requirements, agency communication plans and the time-phased requirements of the control agency. The control agency may assess the capability of the outside agency and specify whether it needs supplementing, and if so, who could provide the additional capability. Local universities may supply interested graduate students. The net result of this activity should be detailed plans specifying how, when and to what degree the outside agency's capabilities will be integrated with that of the control agency during a potential episode.

2.3.3.3 Implementing the Emergency Control Actions

One of the primary responsibilities of the control agency is the planning, coordination and execution of the various emergency control actions. In some cases the stationary source control actions will be specified in the EAP for each alert stage or based upon Emergency Curtailment Plans prepared by the emitter and possibly approved by the control agency (see Section 4.3.4). Typical control actions are presented in Section 4.7.1. Control actions may either be mandatory or voluntary.

In the case of those control actions specified in the EAP the control agency must:

(a) Contact each major affected source and insure that it is aware of the requirements of the EAP,

(b) Determine whether the source can comply with the requirements,

(c) Establish an instrumentality for notifying the source of an impending or required abatement action as, TWX, telephone, alarm, radio, etc.,

(d) Notify the source of the impending and/or required abatement action during an episode,

(e) Inspect some sources during an episode to insure compliance with the plan (whether compliance is mandatory or voluntary).

Agency action for those sources required to prepare an Emergency Source Control Plan are:

(a) Formally notify each affected source of the requirement to prepare curtailment plans by a specific date,

(b) Detail the information required in an Emergency Source Control Plan: emission reduction plan, time for implementation, number of employees affected, emission during transient conditions, etc. (See Section 4.3.3.2.)

(c) Examine the Emergency Source Control Plan for compliance with the requirements. Approve or disapprove the Emergency Source Control Plan (if this is part of the overall EAP),

(d) Notify the source of approval of the plan,

(e) Establish an instrumentality for notifying the source of an impending or required abatement action,

(f) Possibly arrange for direct communication between major sources and the control agency to obtain emission status reports.

The control of mobile sources such as automobiles will in general be voluntary except for "high" alerts. (See Section 4.7.1.) The major features in controlling vehicles will be requests for reduction in unnecessary travel and closing of establishments to reduce the need to travel.

2.3.3.4 Communications

The control of a potential episode requires rapid control response to changes in meteorology and pollutant levels. This makes the design of a communications plan one of the most important elements in the implementation of an EAP. A major portion of the communications network is used to transmit status reports and control actions to non-control-agency personnel. Individuals needing such information include:

Public Officials

Mayor, Governor, city council, health commissioner, etc., who may be called upon to participate in a decision-making process.

Major Emission Sources

Major emission sources require alert status reports to effect source control plans designed to reduce emissions. If execution of such plans is mandatory, a formal system may be required for legal notification of the alert status. For example, the Los Angeles Air Pollution Control District maintains a radio transmitting system which continually broadcasts and is received by most major industrial sources in Los Angeles County during all hours of plant operation. In other areas, telephones and public announcements have been used.

Public Safety Agencies

The police, fire, civil defense, and public health departments may be assigned definite tasks during an alert and need to be kept current on the status of the event. In some locations, existing civil defense, disaster or emergency networks and procedures may be available and can be used. The telephone company, though not a public agency, has similar needs to be informed, mainly because of the possible overloading of facilities.

General Public and News Media

The important thing is that a direct communications link to the major sources of local news media in the area is required. Judgment in dealing with news media is extremely important and consultation with those experienced in such judgment is highly desirable. Sample news releases, one for each alert level, should be kept on file and revised as experience indicates (Ref. 2-1).

2.4 OPERATION OF A TYPICAL EMERGENCY ACTION PLAN (EAP)

In order to illustrate the operation of an EAP, a brief description of the actions of a control agency during an episode is presented in this section. Both the agency and the occurrence are strictly hypothetical with no relationship to any actual event. It is important to realize that the highly sophisticated system described is not a prerequisite to all Emergency Action Plans. A simple EAP may involve only two to three sampling stations, procedures for curtailing emission sources, and a single criterion selected to prevent a disaster.

It is assumed that the control agency employs a four-stage system corresponding to that in Figure 2-3, each stage defined by particular pollutant levels or dosage and forecast meteorological conditions. Only the governor of the state is empowered to call the final alert, which would, in effect, "completely" close down the community. The example outlined below has been formulated from a City College of New York Panel Report on status criteria. This Panel Report is presented in Appendix I.

2.4.1 STAGE I (FORECAST STAGE)

The first indication of the potential episode is the meteorological forecast. The national APPF system informs the agency that potential episode conditions will exist in the area for at least the next 36 hours. The control agency prepares for the potential episode by the following actions:

Intra-agency:

(a) Notifies responsible control agency personnel,

(b) Notifies members of the Emergency Action Committee,

(c) Requests increased meteorological soundings,

(d) Increases the air sampling activity,

(e) Plans personnel assignments to provide for continual manning of control centers,

(f) Activates control center (prepares to contact extra-agency groups),

(g) Checks communications center,

(h) Increases inspection of major sources to assure compliance with abatement regulations,

(i) Uses best judgment to predict future trend of pollutant dosage, since no dispersion model has been programmed.

Extra-agency:

(a) Notifies public officials, police, fire and public health departments of potential episode,

(b) Requests media (TV, radio, newspapers) to advise public of possible adverse situations (optional at forecast stage),

(c) Notifies industry of condition, requests review of selected curtailment procedures. (In some cases power generation might voluntarily switch to gas or low sulfur fuel),

(d) Notifies telephone company of condition and requests activation of planned emergency telephone communications.

Basically, these operations are to ready the system for action during an episode. The primary concern is observing the trend of rising air pollution levels. In this hypothetical case, the automated sampling system indicated steadily rising levels of SO_2 and particulates. The dispersion model predicts that First Alert levels for SO_2 will be reached at 3 of the 10 sampling stations in 10 to 12 hours. The control officer is notified.

2.4.2 STAGE 2 (FIRST ALERT)

First Alert air pollution levels are attained. Meteorological information indicates that this condition will persist for at least 36 more hours. The responsible Control Officer calls a First Alert. Actions immediately taken are as follows:

Intra-Agency:

(a) Control Officer formally declares First Alert,

(b) Meteorological soundings and air sampling are increased,

(c) All agency personnel are notified of schedules for expected duration of emergency,

(d) Field inspections are increased,

(e) Judgment is employed to determine best actions in case Second Alert is achieved and to predict future trends, since no dispersion model has been programmed.

Extra-Agency:

(a) Public officials (police, fire, and public health) are notified,

(b) News media are requested to advise public of adverse conditions using prepared news release. Public is asked to take the following steps:

    (1) Restrict unnecessary travel, use car pools where feasible.

    (2) Reduce residential thermostats, avoid using unnecessary electrical power. (Restrict to 40 watts per room).

    (3) Stay indoors and rest as much as possible.

    (4) Very sensitive individuals consult their doctors.

    (5) Ban all public incineration and all public fires.

(c) Notify industry of First Alert level and request activation of applicable curtailment procedures, namely:

    (1) Power generation facilities switch to natural gas and/or low-sulfur fuel. Recommend switching of maximum load to remote sites and site C which is downwind.

    (2) City incinerators reduced to 50% throughout.

    (3) City schools standby to close if situation persists 24 more hours.

    (4) Specified large fuel users switch to low sulfur fuel oil.

    (5) All industries voluntarily minimize the use of electrical power.

    (6) Specified industries are not to start any new batches.

    (7) Specified industries and commercial operations standby for shutdown operations.

(d) Request Public Health Officials to alert health agencies for shutdown operations and for special data to be acquired.

The results of the industrial curtailments are apparent. Nevertheless, SO_2 concentrations continue to rise (considering diurnal fluctuations) -

but at a much reduced rate. The power company reports public and industry compliance with the request for power reduction as seen in somewhat reduced power demands. The police department reports no discernible decrease in automobile traffic. Listed agency phones are essentially out-of-commission with a large number of calls from the public requesting information and reporting violations, mostly of small quantities of visible smoke. Agency communication is, however, unaffected as separate lines are being used in the control center.

The air sampling system indicates a rapid increase in CO concentration exceeding the First Alert level for this contaminant. The dispersion model predicts that 2nd Alert levels will be reached in 8 to 10 hours for CO and 12 to 14 hours for SO_2 and particulates. Meteorology indicates that a break in the weather can be expected in 24 to 48 hours. The Control Officer recognizes that a Second Alert level will probably be reached and decides with the Emergency Action Committee that an intermediate status report to the public is desirable. At this point, the responsible Control Officer notifies public officials, industry, news media, police, fire and health departments of the continuing emergency and requests that they be ready to implement a Second Alert. The news media informs the public of the probability of a Second Alert and details the actions to be taken if Second Alert levels are reached, namely the closing of many commercial establishments and main freeway arteries.

The results of this announcement are apparent. Within 3 hours the police report slightly reduced automobile activity in the district. CO concentration continues to build up but only very slowly.

2.4.3 STAGE 3 (SECOND ALERT)

The SO_2 and particulate levels, however, continue to increase until finally Second Alert levels are reached. Meteorology informs the control center of a possible alleviating wind movement which may bring rain within 12 to 24 hours. The control officer consults with his technical staff to determine what would occur if no further action is taken. The dispersion model predicts Third Alert levels for SO_2 would be attained in 18 to 24 hours at present emission rates. The Control Officer calls a Second Alert. Actions immediately taken are as follows:

Intra-Agency:

(a) Control Officer formally declares a Second Stage alert;

(b) Control Officer notifies State Governor of impending state of emergency (only Governor can declare Third Alert);

(c) All previous emergency actions continued;

(d) Control Officer notifies agency inspection and enforcement personnel of Second Alert. Request they concentrate inspection on high-sulfur fuel burning facilities required to shut down.

Extra-Agency:

(a) Notifies public officials, including the police, fire and local Public Health officials;

(b) Requests police to close main arteries (freeways, parkways, etc.), as planned;

(c) Requests news media to advise public of continuing adverse condition;

(d) Requests public to continue all previous restrictions;

(e) Informs public of closing of main traffic arteries;

(f) Informs public of which commercial and business activities are curtailed;

(g) Notifies industry and commercial plants of Second Alert and requests activation of applicable curtailment procedures, namely:

(1) All previous curtailment actions remain in force.

(2) All burning of high-sulfur fuel is banned for industry and commercial units unless a permit for critical operation has been issued.

(3) Specified large industries are ordered to shut down or to stand by for shut down per curtailment plans.

(4) All non-essential commercial and business operations employing over 100 employees are ordered closed per curtailment plans.

(5) All restaurants and entertainment establishments are ordered closed.

(6) All incineration (both city and private) are ordered shut down.

Results are immediately apparent. Within two hours, the power company reports greatly reduced loads, permitting it to switch all loads to remote plants. The police department requests a 4-hour delay in closing traffic arteries to permit workers from closing facilities to get home. Permission is granted by Control Officer. Field inspectors report general compliance to the shut down order. Enforcement officers are dispatched to two noncomplying plants. Two of the remote air sampling stations appear erratic. Technicians are dispatched to repair them.

The air sampling data shows a slow reduction in SO_2 and particulate concentrations. CO concentration momentarily increases and then starts to taper off as traffic decreases. Results from a manually-solved diffusion model predict pollution levels should remain constant (at an elevated, damped diurnal frequency). Meteorology predicts a break in the weather front within the next 12 hours.

Pollution levels continue to fall as atmospheric activity starts to disperse the pollutants until finally a light rain begins to fall. Air sampling stations show a rapid decrease in pollution levels. The episode is over.

The Control Officer takes the following actions.

Intra-Agency:

(a) Control Officer formally declares the emergency is over;

(b) Control Officer notifies State Governor of termination alert conditions;

(c) Control Officer notifies all agency employees of termination of alert conditions;

(d) Control Officer notifies all agency employees of termination of alert conditions. Agency personnel goes to minimum crew after taking action to insure all data are secured for post episode report;

(e) Control Officer assigns reporting responsibilities to staff - report for news media has high priority.

Extra-Agency:

(a) Notifies public officials, police, fire and Public Health;

(b) Requests Public Health to start to collect data on mortalities and morbidity;

(c) Requests news media to advise public of termination of alert conditions;

(d) Notifies power and telephone company of termination and warns them to anticipate impact of resumption of normal activities;

(e) Notifies industry, commercial and business facilities of termination of the alert;

(f) Notifies hospitals of availability of atmospheric data to support health studies.

A few days after the episode, the agency begins the preparation of functional post-episode reports: one is for internal distribution and is an evaluation of the effectiveness of the agency operations; one is a technical report of meteorological, sampling and public health data.

The example presented above only serves to illustrate the flow of information in the actual operation of an emergency action plan and many simplifications are made. A real episode plan, for example, would have to consider the actual timing of all events relative to the normal day/night activity cycle of the city. But it does serve to illustrate the major elements of a plan, namely:

(a) Delineation of responsibility (the Control Officer was the sole critical-point decision maker in the plan);

(b) The necessity for effective communications systems for information dissemination;

(c) The importance of real-time air sampling and meteorological data;

(d) The value of a predictive model in decision making;

(e) The need for clear-cut criteria for each alert level;

(f) The need for detailed preplanning of all possible actions;

(g) The need for self-evaluation in a post-episode report.

2.5 REFERENCES

2-1 Personal Communication, New York Department of Air Resources, New York City (Austin Heller), September 1968.

3.0 AIR POLLUTION EPISODES

3.1 A BRIEF ACCOUNTING OF KNOWN AIR POLLUTION EPISODES

The occurrences of air pollution episodes are becoming more frequent with the growth of our society. Reported critical periods of air pollution go back as far as 1873. London has had ten reported episodes since this date. New York City has had seven reported episodes since 1953. At least two of these were general episodes for the entire Eastern United States. (Ref. 3-1, 3-2, 3-3.) Other well known episodes occurred in the Meuse Valley of Belgium and in Donora, Pennsylvania. Minor "incidents" have been reported for St. Louis, Missouri (Ref. 3-4); Cincinnati, Ohio (Ref. 3-5); Wierton, West Virginia (Ref. 3-6); Rotterdam, Holland (Ref. 3-1); Hamburg, Germany (Ref. 3-1); and Osaka, Japan (Ref. 3-1). Critical periods of smog have occurred frequently in Los Angeles, California; and outbreaks of asthma have been reported for New Orleans, Louisiana; for the Tokyo-Yokohama area of Japan.

Many periods of critical air pollution are borderline cases and they may go unreported. An Episode may occur for a short period of time but not be reported in the technical literature because the number of people severely affected is not large enough to attract public attention. The 1953 episode in New York was not reported until nine years later (Ref. 3-7). In a general report of episodes, Goldsmith states that:

> "The toll of excess mortality and morbidity in disasters has never been appreciated at the time; therefore protective measures were not taken" (Ref. 3-1).

Since the causes were not known, they were never reported. However, awareness of air pollution is growing and techniques for monitoring pollution are improving. Episode frequency probably is increasing. The Air Pollution Potential Forecasts (APPF) were initiated on a regular basis in August, 1960 (Ref. 3-2). Advanced warnings of meteorological conditions leading to the accumulation of air pollution are provided by this system. Figure 3-1 shows the frequency of air pollution episodes as reported in technical literature.

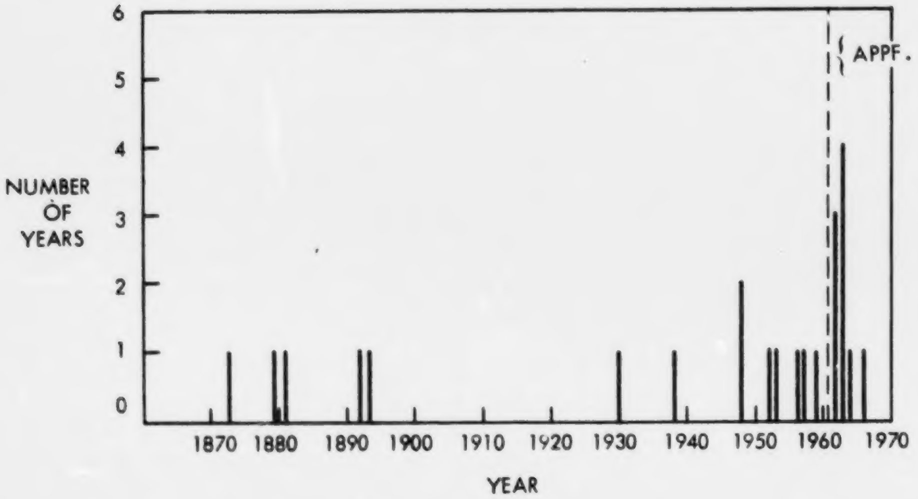


Figure 3-1. Frequency of Air Pollution Episodes

Some general indications about episodes that can be concluded from the reports are:

1. Prolonged anticyclonic weather systems were present
2. Temperature inversions were noted
3. Wind speeds were low
4. Concentrations of smoke, sulfur dioxide, and other pollutants increased to critical levels.
5. Mortality associated with peak concentrations of air pollutants increased
6. Morbidity was also related to air pollution levels.
7. The effects were prompt.
8. Death and illness occurred in all age groups (8).
9. Excess deaths increased with increasing age.
10. Effects of episodes on health seemed to be due to a combination of several pollutants.
11. Deaths were generally the result of respiratory or cardiovascular problems.
12. Cough and eye irritation have been shown to be related to pollution levels (9).

13. The duration of episodes generally ranged from 2 to 7 days.
14. Average sulfur dioxide levels ranged from 0.5 to 0.8 ppm.
15. Species other than man may have succumbed to air pollution.

Detailed documentation is not available on most reported air pollution episodes, especially those occuring before 1957. Lyons, Steigerwald, and Ludwig (Ref. 3-2) have described in some detail the November - December 1962 Air Pollution Episode in the Eastern United States. Figure 3-2 shows the ratio of "episode" to "normal" particulate levels in an elliptical area from New York to Boston during that incident. Benzene soluble organics rose to seven times normal, and total particulate rose to three to four times normal.

Figures 3-3 and 3-4 show CAMP statistics data from Washington, D. C. and Philadelphia, Pennsylvania. Table 3-1 presents selected pollutant dosage calculations. The authors comment as follows:

> "The normal (N) used for comparison is the November-December 1962 period, excluding the episode (E). Generally the 5-8 percent of the month represented by the episode period accounted for from 1/5 to over 1/2 of the dose received during the period, as shown in columns 6 and 7. The average daily dose varied from 1-1/2 to 6 times normal during the episode. Generally this is the result of increased duration of peak concentrations (a lengthening of normal diurnal peaks) rather than striking increases in concentration (columns 2 and 3)."

A compilation of recorded air pollution episodes is presented in Table 3-2 and a compilation of episode history references is presented in Table 3-3.

3.2 METEOROLOGICAL CONDITIONS FOR AIR POLLUTION EPISODES

Air pollution episodes have been associated with atmospheric conditions characterized by sluggish air movement over a period of several days. Under these conditions, in a poorly ventilated, smoke-filled room, concentrations of particulates can accumulate rapidly. To advise when a weather situation of this type is expected, the U. S. Weather

TABLE 3-1. SELECTED POLLUTANT DOSAGE CALCULATIONS

Description	Period	No. of Doses Occurring (Col. 1)	Average Duration of Dose Period Hr:Min (2)	Average Concentration During Dose PPM (3)	Average Dosage Per DDSE Period PPM-Hr (4)	Dosage Per Day PPM-Hr (5)	Percent of Time (6)	2-Mo. Total Dosage (7)
CHICAGO SO_2								
Dosages for concentrations 0.5 ppm.	Normal	146	0:21	0.62	0.22	0.36	94.5	75.6
	Episode	10	1:36	0.66	1.05	3.14	5.5	24.4
PHILADELPHIA SO_2								
Dosages for concentrations 0.3 ppm	Normal	59	0:19	0.44	0.14	1.46	91.8	44.9
	Episode	15	1:50	0.36	0.67	2.00	8.2	55.1
WASHINGTON D.C. SO_2								
Dosages for concentrations 0.3 ppm	Normal	3	1:08	0.33	0.37	0.02	91.8	64.8
	Episode	4	0:26	0.35	0.15	0.12	8.2	35.2
CHICAGO NO								
Dosages for concentrations 0.2 ppm	Normal	147	2:13	0.26	0.57	1.46	94.5	79.8
	Episode	11	5:38	0.34	1.94	6.41	5.5	20.2

TABLE 3-2. EPISODE HISTORY

LOCATION AND DATE		POLLUTANTS		METEOROLOGY	HEALTH EFFECTS	
	Ref	Type	Range		Diseases/Symptoms	Excess Deaths
LONDON Dec. 9-11, 1873	1 2 3	Bla		Fog		650 (a)
Jan. 26-29, 1880	1 2 3 4			Fog		1176
Feb. 1882	1			Fog		Excess deaths noted
Dec. 1891	1			Fog		Excess deaths noted
Dec. 28-30, 1892	1 2 3					779
Nov. 26-Dec. 1, 1948	1 2 3 5	Black Suspended Matter SO_2	200-2800 mg/m^3 0.09-0.75 ppm	Temp (min) 25-43°F (max) 37-54°F Wind Vel. 0-4.6 mph Visibility 27-440 yds.		700-800
Dec. 5-9, 1952	1 2 3 4 5 6 7 8 9 10	SO_2 Black Suspended Matter	0.09-1.34 ppm 400-4500 mg/m^3	Temp (min) 24-39°F (max) 31-40°F Wind Vel. 9-5.8 mph Visibility 22-240 yds Fog	Bronchitis Emphysema Cardiovascular-(ischemic heart disease) Acute Wheezy Chests Dyspnoea Fever Yellow-black sputum	4000 (b)

TABLE 3-2 (Continued)

LOCATION AND DATE	Ref	POLLUTANTS Type	 Range	METEOROLOGY	HEALTH EFFECTS Diseases/Symptoms	 Excess Deaths
LONDON (cont'd) Jan. 3-6, 1956	2 5 6 11	SO_2 Black Suspended Matter	0.19-0.55 ppm 700-2400 mg/m^3	Temp (min) 29-36°F (max) 36-47°F Wind Vel. 0-8.1 mph Visibility 5-12000 yds		1000
Dec. 2-5, 1957	2 4 5 6 12	SO_2 Black Suspended Matter Critical levels set at: SO_2 Black Suspended Matter	 0.40 ppm 200 mg/m^3			200-250
Dec. 5-10, 1962	1 2 4 8 13	Smog SO_2	1.98 ppm highest hourly concentration		Wheezy chests Bronchitis Dyspnoea Fever Yellow Black sputum Heart failure	700
Jan. 7-22, 1963	2					700
NEW YORK, N. Y. Nov. 18-22, 1953	1 2 8 14	SO_2	Concentrations up to 0.86 ppm 2.92-8.38 COH units	Wind ≤ 7 mph Elongated high-pressure system 3000 ft. inversion	Eye irritation Coughing	Excess death noted

TABLE 3-2 (Continued)

LOCATION AND DATE	Ref	POLLUTANTS		METEOROLOGY	HEALTH EFFECTS	
		Type	Range		Diseases/Symptoms	Excess Deaths
NEW YORK, N. Y. (cont'd)						
Nov. 28-Dec. 4, 1962	1 2 15 16 17 18	SO_2	Max peaks >1.0 ppm on many days	Temp. Avg 46-57°F Wind speed ≤2 mph (early morn. & late eve.)	Cardiac Respiratory	
		CO	Max 1-hr avg of 22.4 ppm			
		SO_2	0.07-1.5 ppm (daily avg)			
		Smoke Shade	2-7 COH units			
		SO_2 (24 hr avg)	0.1-0.7 ppm			
Dec. 30, 1962-Jan. 15, 1963	16	SO_2 (24 hr avg)	0-0.5 ppm	Followed 8 days after very cold spell. Very few atm. inver. Few hrs with winds <5 mph		Excess death noted
		Smoke Shade	1-6.0 COH units			
Jan. 29-Feb. 12, 2 1963	2 16 19	SO_2	0.2-0.5 ppm	Few winds <5 mph Few inversions Stagnating anti-cyclones were absent	Influenza Pneumonia Vascular lesions Cardiac	200-400
		Smoke Shade	1.5 to 7 COH units			
		SO_2 (Avg hourly)	0.46 ppm			
		Smoke Shade	47% of days ≥4 COH units 73% of days ≥0.40 ppm			
Oct. 10-27, 1963	17 18	SO_2	Avg >0.30 ppm for sustained periods	Temp. Avg >60°F Few winds <2 mph Peak of drought period		
		CO	Max 1-hr avg - 27.5 ppm			
		Total Hydrocarbons	- general level 3.0 ppm			

TABLE 3-2 (Continued)

LOCATION AND DATE	Ref	POLLUTANTS Type	POLLUTANTS Range	METEOROLOGY	HEALTH EFFECTS Diseases/Symptoms	HEALTH EFFECTS Excess Deaths
NEW YORK, N. Y. (cont'd) Feb. 27-Mar. 10, 1964	16	SO_2 Smoke Shade	0.0-7 ppm 2-5 COH Units	A few inversions A few winds <5 mph		Excess death noted 168
Nov. 23-25, 1966	2 20 21 23 24 25	SO_2 Smoke Shade CO	0.02-1.02 ppm 0.5-8.2 COH units 1-13 ppm	Temp (min) 34-49°F (max) 49-65°F Wind Speed 2.7-5.6 mph Temp Inver. during a.m. & p.m. Anticyclonic conditions Vertical Mixing depths 1214 to 1813 feet	Influenza Pneumonia Heart Disease Bronchitis Asthma Malignant Neoplasms of Respiratory system Vascular lesions of CNS	
DONORA, PENN. Oct. 27-31, 1948	1 2 3 4 10 22 26 27	SO_2 (last day) H_2SO_4 mist Other sulfur compounds O_3 NO_X Organic comp Smoke	Concentrations unknown " " " " " "	Temp. Inversion Fog Stagnant Anticyclone	Cough Respiratory irritation Sore throat Chest constriction Dyspnoea Eye irritation Vomiting Nausea Heart diseases Bronchitis	

TABLE 3-2 (Continued)

LOCATION AND DATE	Ref	POLLUTANTS		METEOROLOGY	HEALTH EFFECTS	
		Type	Range		Diseases/Symptoms	Excess Deaths
MEUSE VALLEY, BELGIUM Dec. 1930	1	SO_2	Concentrations unknown	Fog	Cardiovascular	60-80 (e)
	2			Wind speed -0.62 mph	Hypotension	
	3	H_2SO_4	"	Ceiling - 246 ft.	Alkalosis	
	10	HF	"	Temp. Inversion	Sore throat	
	26	NO_2	"		Cough	
	28	CO	"		Nausea	
	29	CO_2	"		Vomiting	
EASTERN U. S.						
Nov. 27-Dec. 5, 1962 (2-7 1/2 days)	1 15	Avg. Organic Particulate was 6 (f) times normal level Avg. Particulate was 2-3 times (f) normal level (Avg. of 3-13 cities)		Quasi-stationary anticyclone Low Winds		
WASHINGTON, D. C.		SO_2	0.04-0.29 ppm			
		CO	2-24 ppm			
		Total hydrocarbon	2-17 ppm			
		Total Oxidants	0-0.017 ppm			
PHILADELPHIA, PENN.	SO	SO_2	0.04-0.45 ppm	Temp. 42-50°F		
		NO	0->0.65 ppm			
		NO_2	0-0.22 ppm			
		Hydrocarbon	1-10 ppm			
		Total Oxidants	0.-0.01 ppm			

TABLE 3-2 (Continued)

LOCATION AND DATE	Ref	POLLUTANTS Type	POLLUTANTS Range	METEOROLOGY	HEALTH EFFECTS Diseases/Symptoms	HEALTH EFFECTS Excess Deaths
EASTERN U. S. (1962 cont'd)						
CINCINNATI, OHIO		SO_2 NO NO_2 Hydrocarbon Total Oxidants Ozone	0.01-0.28 0-0.57 ppm 0.03-0.23 0.3-1.7 ppm 0-0.025 ppm 0-0.008 ppm	Temp. 45-52°F		
CHICAGO, ILLINOIS		SO_2 NO NO_2	0.05-0.87 ppm 0.11-0.59 ppm 0.04-0.18 ppm	Temp. 45-51°F		
NEW YORK, N. Y.		SO_2	0.07-1.50 ppm	Temp. 46-57°F		
EASTERN U. S. Nov. 20-26, 1966		SO_2 levels peak in morning		Light winds Poor horizontal ventilation Stagnating high pressure system		
		(Pollutant Ranges listed below are 24 hour means)				
PITTSBURGH, PENN.				Avg. Temp. 32-53°F P.M. Mixing depth 990-3320 ft. Avg. Wind speed 5.5-12.5 mph		
BIRMINGHAM,		Soiling Index	0.5-2.2 COH units	Avg. Temp. 51-65°F P.M. Mixing depth 2460-3600 ft. Avg. Wind speed 1.6-9.2 mph		

TABLE 3-2 (Continued)

LOCATION AND DATE	Ref	POLLUTANTS		METEOROLOGY	HEALTH EFFECTS	
		Type	Range		Diseases/Symptoms	Excess Deaths
NEW YORK, N. Y.		SO_2 CO^2 Soiling Index	0.01-0.07 ppm 1-13 ppm 2.8-6.0 COH units	Avg. Temp. 36-54°F P.M. Mixing depth 540-3600 ft. Avg. wind speed 3.9-10.8 mph		Approx. 24/day
WASHINGTON, D. C.		SO_2 NO^2 Hydrocarbons	0.01-0.07 ppm 0.04-0.48 ppm 3-6 ppm	Avg. Temp. P.M. Mixing depth 630-5100 ft. Avg. Wind speed 3.6-8.5 mph		
BOSTON, MASS.		SO_2 Suspended Particulate	0.11-0.30 ppm 45-220 mg/m^3	Avg. Temp. 34-51°F P.M. Mixing depth 845-4060 ft. Avg. Wind speed 6.0-9.5 mph		
PHILADELPHIA, PENN.		SO_2 NO^2 NO_2 Hydrocarbons CO Susp. Particulate Soiling Index	0.03-0.26 ppm 0.04-0.48 ppm 0.03-0.08 ppm 3-5 ppm 0-10 ppm 80-390 mg/m^3 0.8-3.8 COH units	Avg. Temp. 36-53°F P.M. Mixing depth 845-3880 ft. Avg. Wind speed 4.5-9.2 mph		
NEWARK, N. J.		SO_2 NO^2 NO_2 Hydrocarbons CO Soiling Index	0.12-0.40 ppm 0.-0.40 ppm 0.02-0.14 ppm 1-13 ppm 15-32 ppm 1.5-6.5 COH units			
BALTIMORE, MD.		Susp. Particulate Soiling Index	20-220 mg/m^3 0.7-1.8 COH units			

TABLE 3-2 (Continued)

LOCATION AND DATE	Ref	POLLUTANTS		METEOROLOGY	HEALTH EFFECTS	
		Type	Range		Diseases/Symptoms	Excess Deaths
EASTERN U. S. (1966 cont'd)						
LOS ANGELES, CALIF.	25	Ozone Hydrocarbons NO_x		Frequent prolonged temp. inversions Smog	Eye irritation Mild resistance to perspiration	
CINCINNATI, OHIO May 16-17, 1962	30	Max. Hourly Concentration Total Oxidant:		Temp. >90°F Avg. Wind speed <4 mph Quasi-stationary anticyclone Clear skies High degree of insolution Nocturnal radiation inversion (formed each nite) varied 200-400 ft.		
		5/16	0.14 ppm			
		5/17	0.19 ppm			
		NO 5/16	0.13 ppm			
		5/17	0.13 ppm			
		NO_2 5/16	0.20 ppm			
		5/17	0.24 ppm			
NEW ORLEANS, LA. (Since early 1950's)	31 32 33 34 35	Silica Crystal Particle (city dump) Emissions from public elevator also suspected.		Assoc. with winds of very low velocity	Asthma outbreak(9)	
TOKYO-YOKOHAMA JAPAN 1946-1963	35 36	Dustfall Sulfation Pollution particularly noticeable in fall and winter (eve. & nite)	No data No data	Met. cond. unfavorable for removing air pollution	Acute Bronchitis Asthma Accute attacks coincided with periods of concentrated air pollution. People leaving area; become ill again on returning.	

TABLE 3-2 (Continued)

LOCATION AND DATE	Ref	POLLUTANTS Type	Range	METEOROLOGY	HEALTH EFFECTS Diseases/Symptoms	Excess Deaths
MINNEAPOLIS, MINN., 1956	1	Emissions from processing plants of grain industry			Asthma outbreaks	
WEIRTON, W. VA. Prior to Sept. 1960	32	Assoc. with Carbon Monoxide effluent from industrial stacks		Inversion layer, with stagnation	13 people hospitalized	
ROTTERDAM Dec. 2-7, 1962	1	SO_2	5 times normal			Increase in mortality noted
HAMBURG Dec. 3-7, 1962	1	SO_2 Dust Pollution	5 times normal 2 times normal			
OSAKA, JAPAN Dec. 7-10, 1962	1	Pollutions levels high				60
ST. LOUIS, MO.(h) Nov. 28, 1939	37	Smoke	(nighttime darkness through the day)	Temperature inversion Windless period		

(a) Also cattle.
(b) Also cattle; excess deaths calculated on 7 and 15 day moving average.
(c) Excess deaths calculated on 7 day moving average. Deaths occurred on first day. Morbidity coincided closely with mortality.
(d) 43% of population were affected.
(e) Also cattle.
(f) Average of 3-13 cities.
(g) 100 emergency room visits at one hospital with two resulting deaths.
(h) Known as "Black Tuesday."

TABLE 3-3

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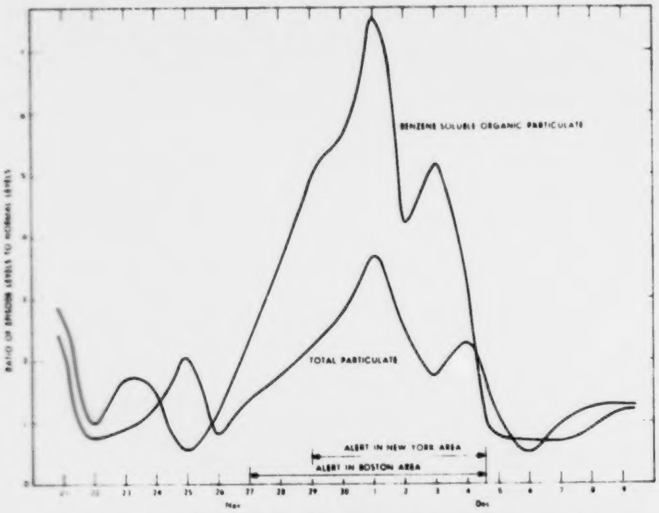


Ratio of pollutant levels during episode to normal pollutant levels in the Boston - New York area.

Figure 3-2. Episode to Normal Particulate Levels

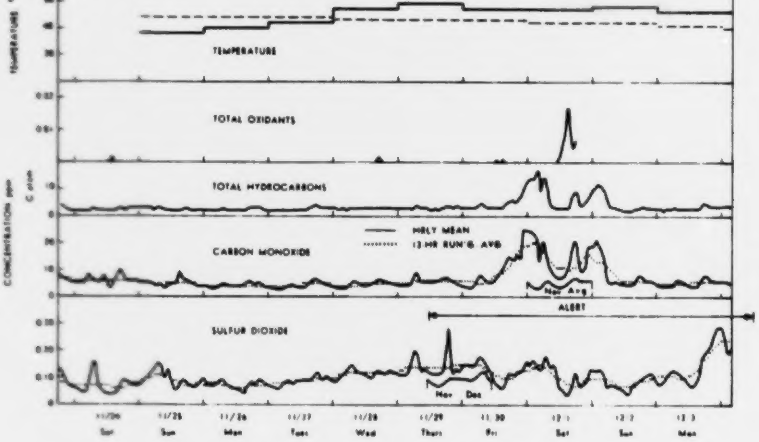


Figure 3-3. CAMP Statistical Data, Washington, D. C.

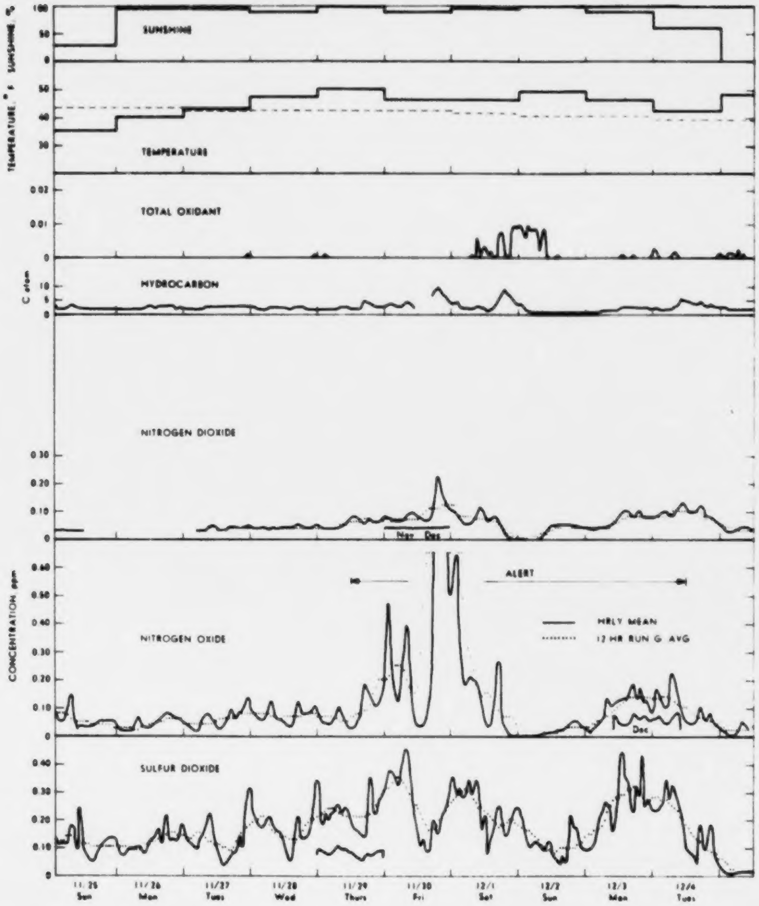


Figure 3-4. CAMP Statistical Data, Philadelphia, Pennsylvania

Bureau issues daily messages under its Air Pollution Potential Forecast (APPF) Program, which is further described in Section 4.4.1. For these purposes, a semi-arbitrary set of "technical" conditions has been selected for defining high air pollution polential;

In general terms, a description of weather conditions common to air pollution episodes is as follows:

(a) A high-pressure system becomes almost stationary over the area for several days

(b) No precipitation occurs

(c) Temperatures are generally above normal

(d) Winds are between 0 and 7 miles per hour near the surface, and relatively light aloft to at least 18,000 feet (500 millibars)

(e) Air at these higher elevations is slowly sinking and warming (subsidence)

(f) Air in the low levels is stable, that is, exhibits little motion or mixing in the vertical

(g) Temperatures in these layers increase with height (inversion) instead of decreasing as they normally do.

From a meteorological standpoint, a weather situation conductive to the occurrence of high concentrations of air pollutants is said to have "high pollution potential," whether pollutant sources actually exist in the underlying area or not.

Further discussion of air pollution episode meteorology appears in paragraphs 4.4.1 and 4.5.

3.3 POLLUTANT LEVELS AND HEALTH EFFECTS OF AIR POLLUTION EPISODES

High concentration of man made pollutants in the air has resulted in the following observed effects:

(a) reduction of visibility

(b) deterioration of fabrics, metals, and building materials

(c) damage to vegetation and animals

(d) injury to man himself

If, under "chronic" conditions, the pollutant levels are sufficient to produce some of these manifestations, then under acute (episodic) conditions these effects could interact to create an emergency, or perhaps a disaster.

The major source of urban air pollution is energy-conversion, although some pollutants, such as flourides or beryllium, are manufacturing by-products. Pollutants can be classified into four broad categories of material (Ref. 3-8):

TYPE	EXAMPLES
Particulate Matter	Cabonaceous particles, tars, oils, insoluble metal fumes and dusts, amorphous lead, organic debris
Irritants	Soluble dusts, volatile hydrocarbons, Acidic mists, vapours, and gases (e.g., SO_2 or No_2)
Oxidants	Ozone, aldehydes, olefin, peroxyacetyl nitrate
Systemic Poisons	CO, H_2S, cyanides, nicotine, pesticides

Certain pollutants have known properties with respect to health effects, although often the effects have been noted at concentrations higher than would be expected in a normal atmosphere.

3.3.1 DUST FALL

Dustfall, including suspended particulates, must get into the lung to be most damaging. This is dependent upon particle size and aerodynamic properties, although in general the large particles (6μ and over) tend to be screened out by the hose, and the very small particles (below 1μ) tend to behave like gases, and are exhaled without reaching the lung. Inhalation of many dusts, such as India ink, charcoal, calcium carbonate, aluminum, and coal dusts have resulted in an increased airway resistance in man (Ref. 3-9). Patients affliected with chronic lung disease tend to react more rapidly to the airway resistance effect of inert dust (Ref. 3-10). The effects of coal dust in man are depicted in Figure 3-5.

3.3.2 SULFUR DIOXIDE

Sulfur dioxide, a ubiquibus by-product of fossil fuel combustion, is one of the irritants frequently accused in air pollution episodes. Increased airway resistance and tissue irritation have been experienced in human laboratory studies. (Ref. 3-11) Although most SO_2 is absorbed in the nose, changes in resistance have been noted within three seconds after exposure to 5 ppm (Ref. 3-12, 3-13, 3-14). Dust particles can act as

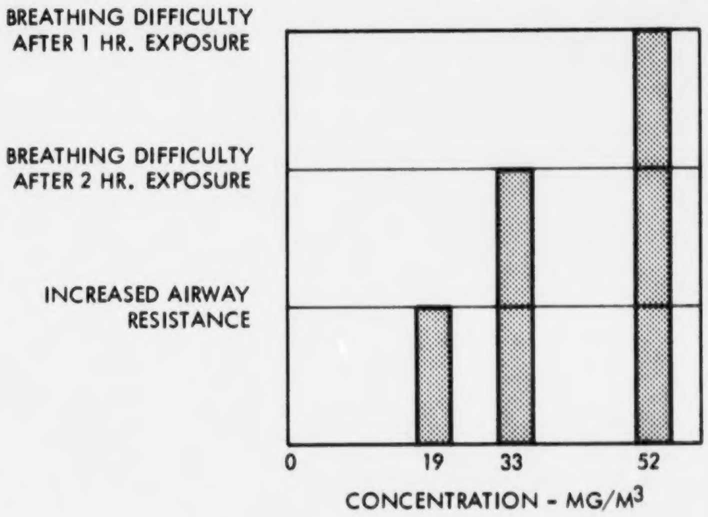


Figure 3-5. Coal Dust - Effect in Man

nuclei in the formation of sulfuric acid mist from fog and sulfur dioxide; this acid mist is a very strong irritant and can cause choking at relatively low concentrations. It produces, on a molar basis, from 4 to 20 times the physiologic response in animals as sulfur dioxide (Ref. 3-15). The effects of SO_2 in man are depicted in Figure 3-6.

3.3.3 OXIDANTS

Oxidant pollution, which occurs as a result of photochemical change under ultraviolet light and whose precursors are found primarily in automobile exhaust fumes, has been correlated in varying degrees with aggravation of chronic respiratory illness (Ref. 3-16, 3-17, 3-18). Two of the most prevalent oxidants are ozone, which causes pulmonary edema, and peroxyacetyl nitrate, often related to eye irritation (Ref. 3-19). Two common precursors of oxidants that are of themselves toxic are: carbon monoxide, which interferes with the oxygen-transport system of the blood, and the oxides of nitrogen, which can produce pulmonary edema and bronchiolitis. The effects of CO in man are illustrated in Figure 3-7. The effects of ozone and NO_2 are shown in Figures 3-8 and 3-9, respectively.

3.3.4 POLYCYCLIC HYDROCARBONS

Polycyclic hydrocarbons, resulting from the combustion of gasoline and coal for the most part, have been correlated to some extent with the incidence of lung cancer (Ref. 3-20, 3-21), and with bronchitis (Ref. 3-22) in man.

Most of the demonstrable toxicity of these pollutants has been the result of laboratory studies or exceptional events and the demonstrations reflect the effect of pollutant levels much higher than is usually encountered in the atmosphere. This is not to say that such levels have not or will not happen during episodal state. It is probable that the combination of two or more pollutants, catalyzed by fog or sunlight and under the right meterologic conditions, produces effects that are more than additive (that is, synergism).

The following tabulation illustrates the variability in episodic atmospheres as indicated by the ranges of pollutants recorded for a sample of 20 episodes (Ref. 3-11, 3-15, 3-23, 3-24, 3-25, 3-26).

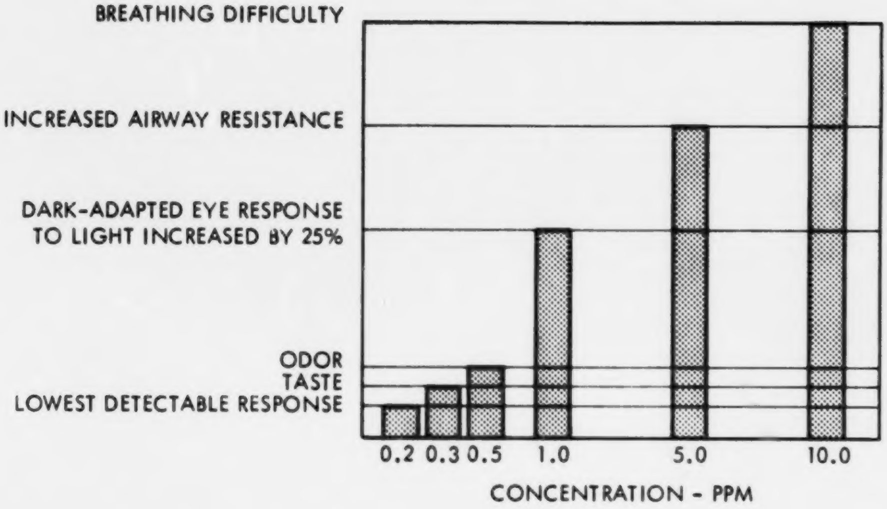


Figure 3-6. SO_2 - Effect in Man

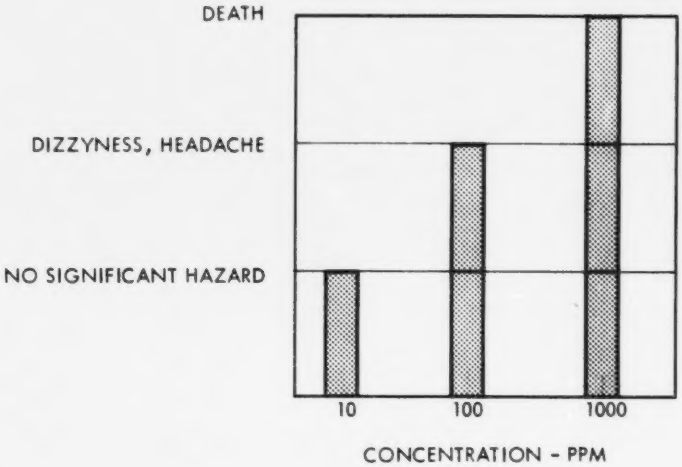


Figure 3-7. CO - Effect in Man

(NOT PRECISELY THE SAME AS THE PHOTOCHEMICAL OXIDANT BUT FAIRLY CHARACTERISTIC)

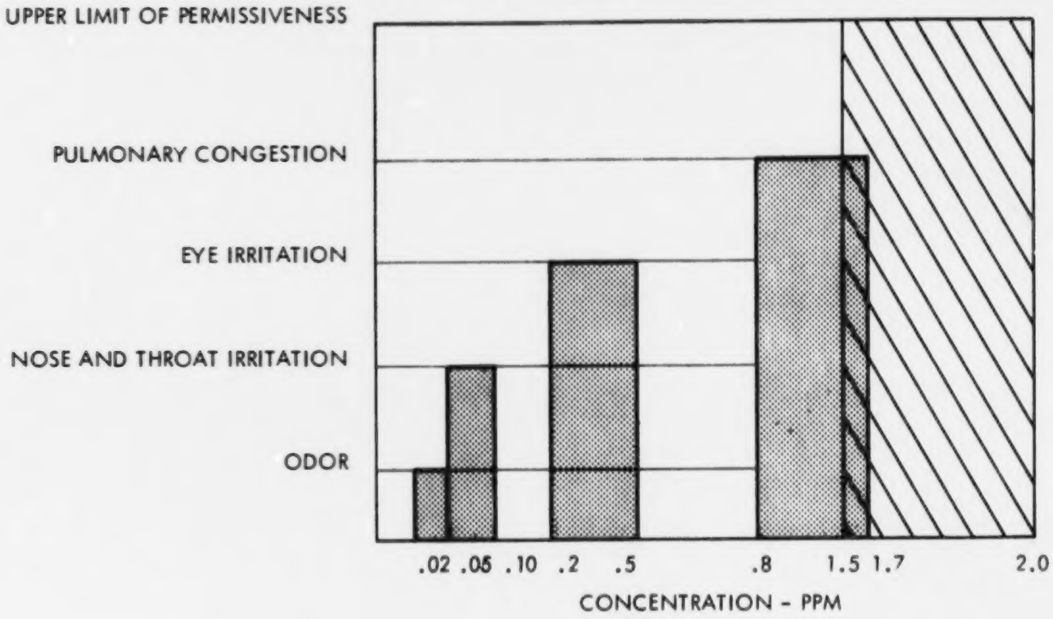


Figure 3-8. Ozone - Effect in Man

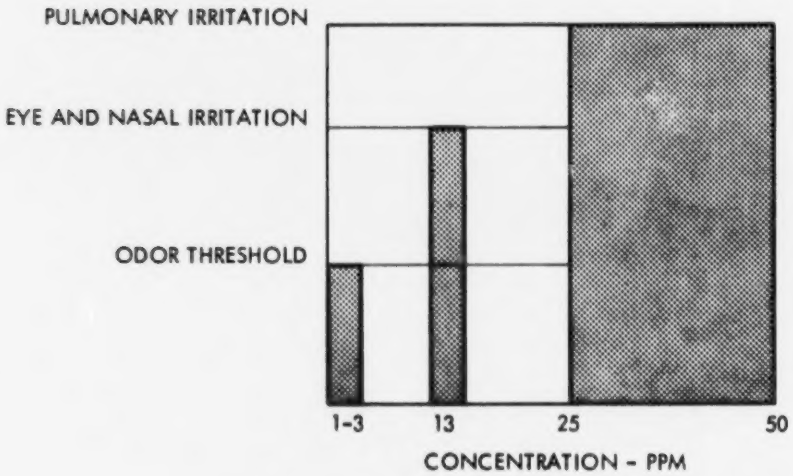


Figure 3-9. NO_2 - Effect in Man

POLLUTANT	RANGE	AVERAGE
SO_2	0-9.8 ppm	0.45 ppm
Particulates	200-4500 mg/m^3	1760 mg/m^3
Smoke Shade	1.0-8.4 cohs	4.3 cohs
CO_x	1.0-27-5 ppm	9.5 ppm

Ten of the 20 were accompanied by fog; all appeared to be directly associated with temperature inversion. Effects on people in these areas were characterized by complaints of eye irritation, upper respiratory involvement, shortness of breath, aggravation of chronic lower respiratory and cardiovascular ailments, and in some cases led to death. Excluding the Donora episode in which the excess death rate reached 1.54 per thousand population, excess death rate during the other 19 averaged 0.124 per thousand, with a range from 0 to 0.6 per thousand.

A great deal of research continues, exploring the relationships between pollutant levels and effects on health. The answers to many of the questions of interaction among pollutants and of "no-effect" doses in man may not be answered for a long time. In addition, the types of pollutnats may change over the years due to new industrial or power-generating techniques; what is of prime monitoring importance today may be of little concern in the future, having been eliminated, or replaced, by new pollutants.

3.4 THE NEED FOR A LOCAL DEFINITION OF AIR POLLUTION POTENTIAL

There is considerable variation in the kind and degree of air pollution potential across the United States. The main factors causing these differences are emission characteristics, meteorology, and topography. For planning purposes, it is desirable to appreciate the nature of these differences and it is necessary to identify the local "character" of a given area.

Emissions important in episodes are the same as those important in "chronic" air pollution. Generally, these are sulfur dioxide, particulates and oxidants, or combinations of these in different proportions. It is a familiar fact that oxidants are at present the greatest recognized problem in Los Angeles; particulates and sulfur dioxide are more serious problems on the eastern seaboard. The need for basing emergency control actions on the local problem is clear. Plans must be flexible, because emission characteristics are certain to change with time in kind and quantity, with improved but unequal control of pollutants. The absence of a satisfactory preventive for NO_x emissions and the growth of the automobile population is a case in point.

Diurnal variations are a part of the local "character," and could influence the strategy of calling "alerts." See Figure 3-10. Seasonal variations, such as predominately oxidant pollution in summer and sulfur dioxide in winter, may exist in many areas; this is the case in Washington, D. C. and Nashville, Tennessee.

The meteorological character of a region depends on geographical location and local topography. Location identifies the broad-scale weather patterns which dominate the area, while topography accounts largely for local variations during particular weather situations. The Environmental Science Services Administration (ESSA) has adopted a classification based on similarity of weather conditions wherein the contiguous United States is divided into the following eight atmospheric areas:

Great Lakes - Northeast Area
Mid-Atlantic Coastal Area
Appalachia Area
South Florida Area
Great Plains Area
Rocky Mountain Area
Washington Coastal Area
California-Oregon Coastal Area

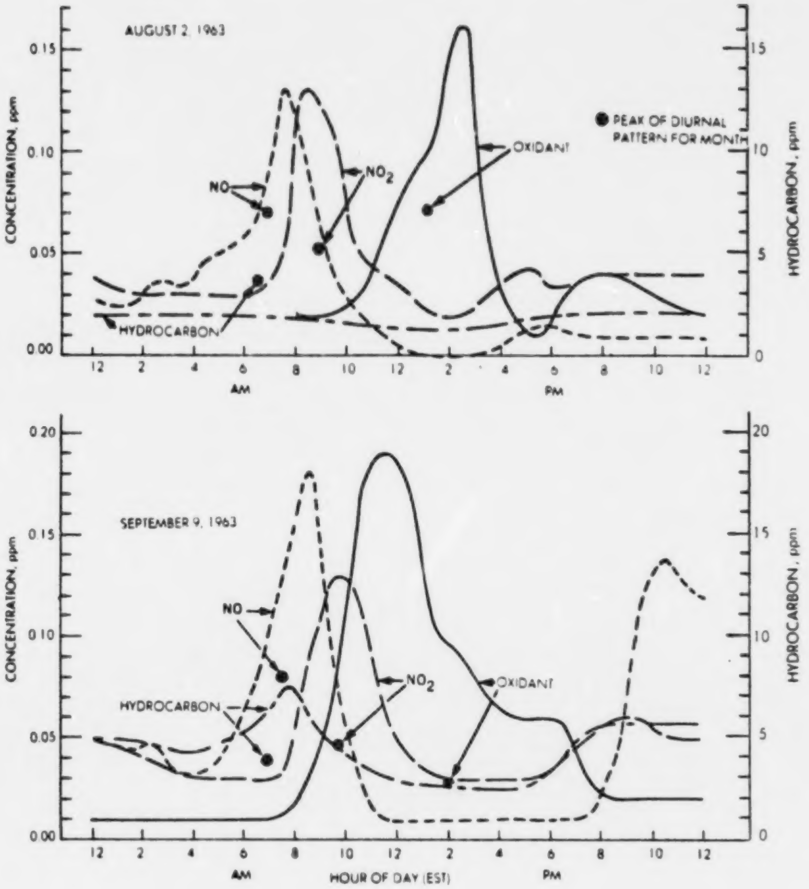


Figure 3-10. Pollutant Levels during Incidents of Photochemical Smog Formation

Of these, the Appalachian and Rocky Mountain Areas are most likely to be dominated by stagnant air masses and light winds. The other areas are normally well-ventilated except for local and transitory variations. Isolines showing "days of stagnation" are shown in Figure 3-11.

Topographic factors that influence air circulation and the distribution of pollutants may be grouped as follows:

(a) Terrain:
Roughness, profile, slope, elevation, valley spacing, valley width. Flat, open terrain is more exposed to broad-scale movement of air than is rough, mountainous terrain, and is generally less subject to air pollution episodes.

(b) Vegetation:
Dimensional characteristics, physical properties, distribution. Heavily wooded clusters tend to develop a micro-climate under the leafy canopy, marked by light winds and temperature inversion. Pollutants entering this regime may accumulate and persist longer than in nearby open areas.

(c) Hydrology:
Shape, size, distribution, and dynamic properties of nearby water bodies. Adjacent land and water surfaces absorb and radiate solar heat differently; the resulting contrast in temperature helps to drive the land-sea breeze during the warmer months of the year. In coastal communities, when the wind systems are weak, pollution tends to "slosh back and forth" with the diurnal reversals of the surface wind, moving off the coast at night and returning inland by day.

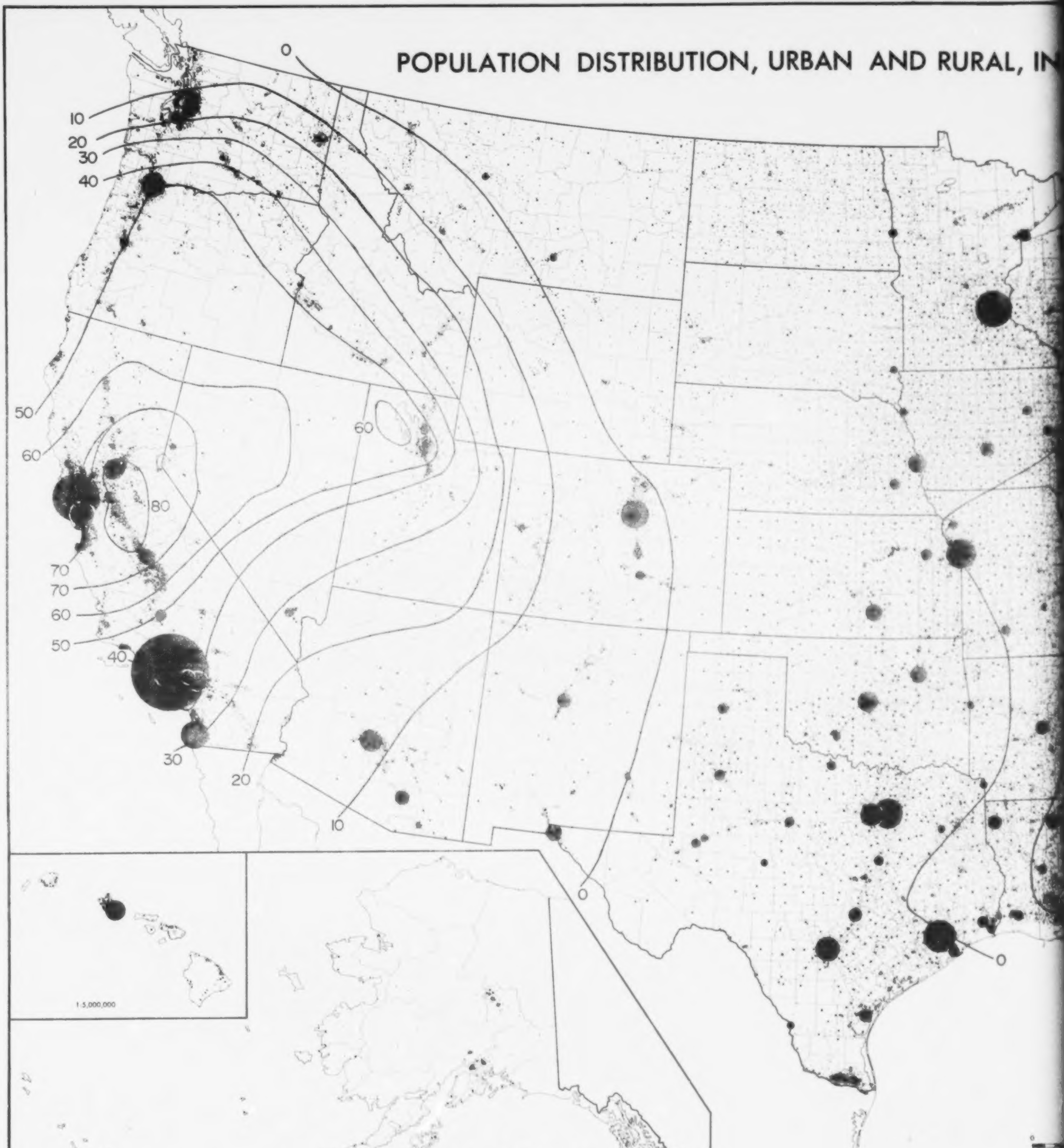
(d) Culture: Degree of Urbanization.
Compared with surrounding countryside, cities influence local weather and pollution distributions in the following ways:

(e) Winds:
Man-made structures reduce the wind speed and channel the flow through streets that lie along the general wind direction. Under some conditions, pollutants become distributed in waffle-shaped patterns following the city plan of streets. Peak concentration may be lowered.

(f) Temperature:
Buildings retain incident daytime heat and re-radiate at night to the surrounding air, thus acting to warm it through a layer that is several times higher than the urban skyline.

UNITED STATES
DEPARTMENT OF COMMERCE

POPULATION DISTRIBUTION, URBAN AND RURAL, IN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Prepared by Geography Division, Bureau of the Census, U. S. Department of Commerce
Subject data from the 1960 Census of Population

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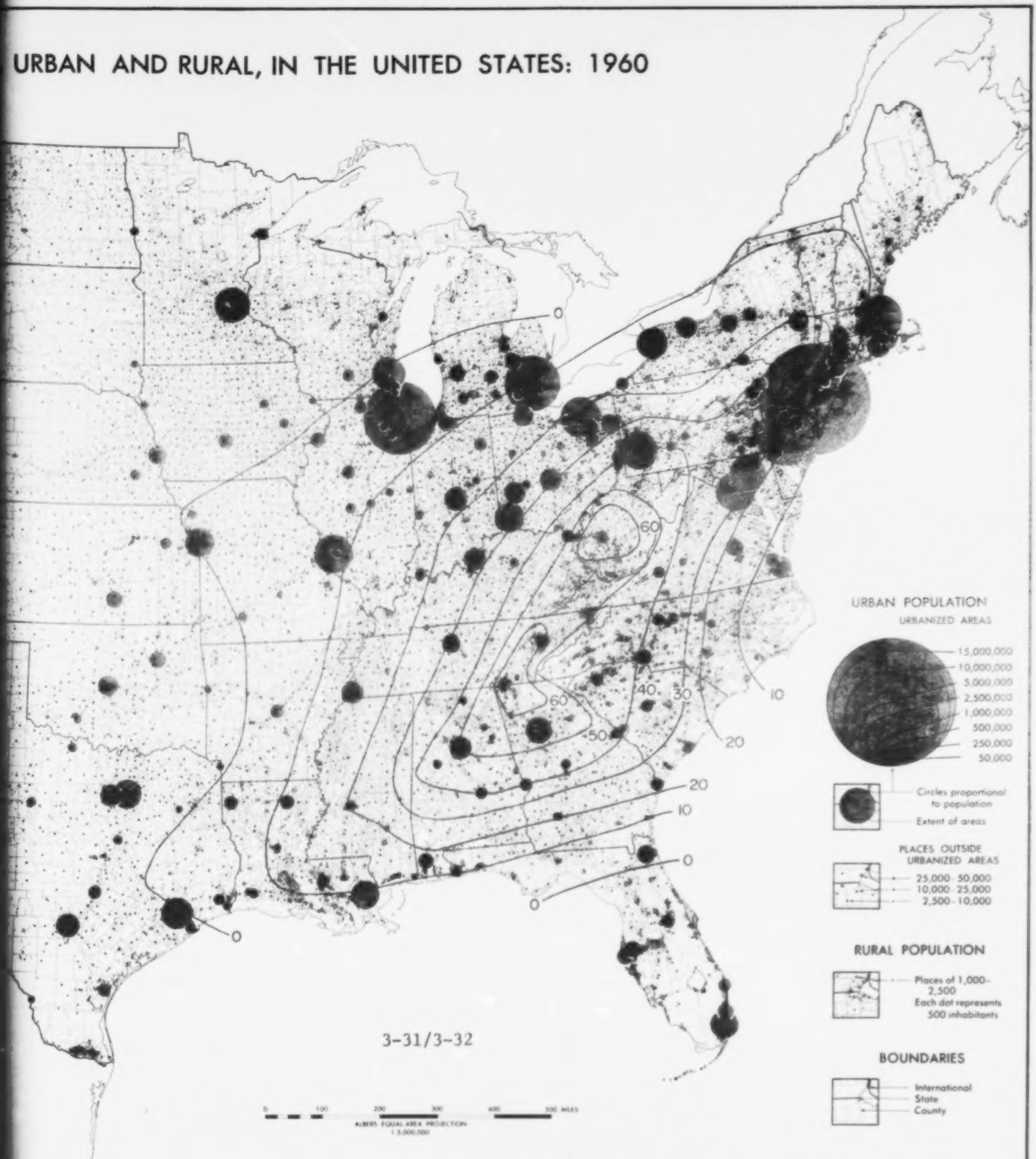
URBAN AND RURAL, IN THE UNITED STATES: 1960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5,000,000
2,500,000
1,000,000
500,000
250,000
50,000
Circles proportional to population
Extent of areas
PLACES OUTSIDE URBANIZED AREAS
25,000 - 50,000
10,000 - 25,000
2,500 - 10,000
RURAL POPULATION
Places of 1,000–2,500
Each dot represents 500 inhabitants
BOUNDARIES
International
State
County
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100
200
300
400
500 MILES
ALBERS EQUAL AREA PROJECTION
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POPULATION DISTRIBUTION, URBAN AND RURAL, IN THE UNITED STATES: 1960

(g) Turbulence:
The higher temperature, rougher profile, blocking of wind, and net influx of air into the city act to increase vertical motions of the air above the city. Pollutants which might otherwise accumulate under a nocturnal temperature inversion become distributed through the thicker layer of atmospheric mixing above the city.

(h) Other Effects:
The above effects, plus the added presence of particulate matter act to increase cloudiness and precipitation near a city, particularly downwind from it; precipitation is effective in removing pollutants from the air.

Combinations of topographic factors coupled with atmospheric processes which vary with season, time of day, and cominating weather-map systems, produce complex local wind patterns. Two patterns associated with the following terrain configurations are especially important in air pollution studies:

(a) Ridges
Winds tend to follow the orientation of ridges and troughs in "ribbed" or "washboard" terrain. Communities may be receptors for pollution that is channeled over considerable distances along the valleys.

(b) Cup-Shaped Valleys
An industrial valley that is virtually surrounded by peaks and ridges is particularly prone to hazardous levels of air pollution. During clear, still nights, cold air collects in pools and pockets at the valley bottom and may persist for long periods of time. Daytime heating sets a mountain-valley circulation in motion, but often pollutants are contained within the valley geometry while winds from an overriding WEATHER MAP system fail to penetrate the heavy air below. A community nestled in this terrain may appear picturesque within a morning blanket of fog and smoke, but it could also be a "potential Donora."

3.5 LOCAL CRITERIA FOR AIR POLLUTION EPISODES

Complete understanding of health requirements may never be realized. The objective of health protection will continue to be to make best use of the knowledge at hand. As more sensitive detection methods and research on health effects are developed, new guidelines emerge to guide decision making.

Deciding what pollutants require control in a given locality now depends mostly on past research, historical occurrence, and a common sense view of existing and forecast emission source contributions to the atmosphere. Sulfur dioxide, carbon monoxide, hydrocarbons and their photochemical products, oxides of nitrogen and particulate matter are of universal interest; one or another may be the principal problem in a given area at a given time. Reduction of these air contaminants -- mostly associated with fuel combustion -- will have an impact on air concentrations of "trace metals" and other low-concentration pollutants. Individual sources may contribute fluorides, chlorides, and many kinds of particulates in small areas, but these are a minor concern in a "first attack on episodes" where the concern is protecting general health in whole cities and regions.

Some pollutants may not be toxic by themselves, but may act as catalysts in the formation of toxicants, or as synergists in combination with toxicants. One fact that emerges from available information is that mixtures of pollutants can be more harmful than the sums of their separate effects indicate. At present, there is no good way of expressing this fact to influence judgment except in the most general terms. Severe effects on sensitive people, such as the aged and infirm, must be taken into account. For this reason, industrial "threshold limit values" are helpful only as starting points, or rudimentary guidelines, because they are standards for exposure of normal, healthy adults for a normal 40-hour work week, and because they provide no indication of synergistic response.

Some useful references on this point are:

(a) "Air Pollution," Vol. I, edited by Arthur C. Stern, Academic Press, N. Y., 1968.

(b) "Air Pollution Handbook," Magill, Holden, and Ackley, McGraw-Hill, 1956.

(c) "Air Conservation," Report of the Air Conservation Commission, AAAS Publication No. 80, Washington, D. C., 1965.

Some local emission and monitoring data are probably essential to prepare a case for a given framework of alert criteria. In the absence of several years of monitoring data, the most satisfactory method is to monitor enough to obtain a reliable frequency distribution. This data will include the required statistics (geometric and arithmetic) for description of the seasonal and "chronic" atmospheric environment. However, unless episodes occur during collection of these data, estimates of "episodic concentrations" will not be obtained, and alert criteria will have to be based on the relations between "episode" and "chronic" observations for places with similar meteorological potential, and on health-effects data. Episodic concentrations have ranged from 2 to 7 times the chronic.

Alert criteria will probably vary from area to area, partly because sampling for pollutants judged (carefully) at the time to be insignificant for episode avoidance amy not be the best use of funds at hand.

Some regions are presently setting alert levels on a dosage of "PPM-hour" basis. A useful tool is the graphic aid shown in Figure 3-12. Dosages corresponding to mortality, morbidity, response threshold, and no discernible effects are displayed. (Response boundaries can be described mathematically with presently available computer programs; "contours" can be drawn directly as a computer output to represent effects which are at least partially quantifiable.) Other graphic aids are shown in Figures 3-13 and 3-14.

3.5.1 WATCH

A "watch" would be called following an APPF advisory that stagnant conditions may be expected to persist for 36 hours or longer.

FIRST ALERT

Parameter	Concentration C	Time
SO_2	0.5 ppm	6 hours
CO	25 ppm	6 hours
Soiling	4.5 COHS	6 hours

3.5.2 FIRST ALERT

A FIRST ALERT would be recommended for any two of the above conditions for the time period shown, or SO_2 alone for the time period shown, if there is reasonable assurance that stagnant weather conditions would continue for an additional 24 hours.

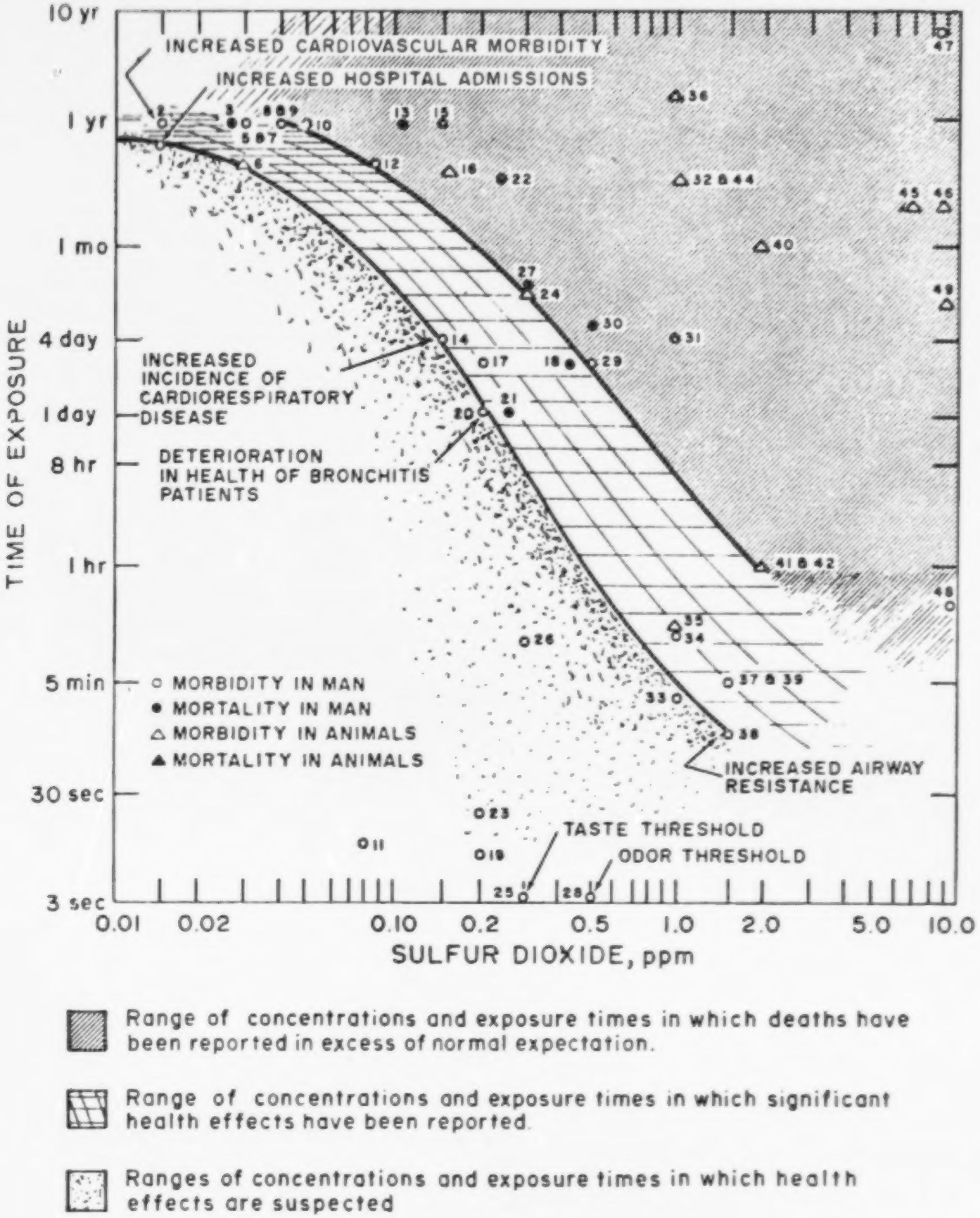

Figure 3-12. Effects of Sulfur Oxides Pollution on Health

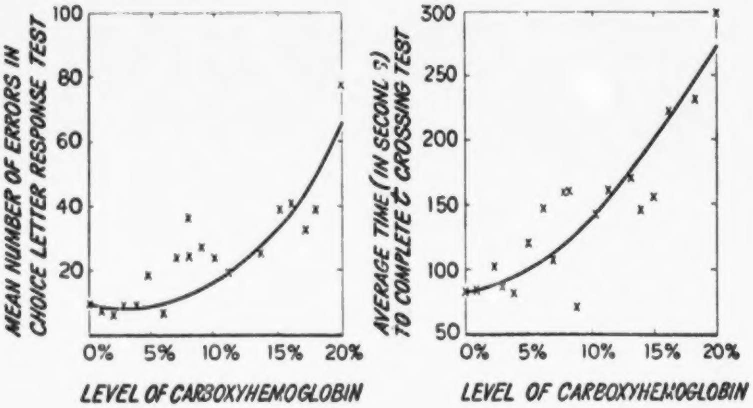

Figure 3-13. Effect of Mild Carbon Monoxide Intoxication on Cognitive and Psychomotor abilities of Human Volunteers

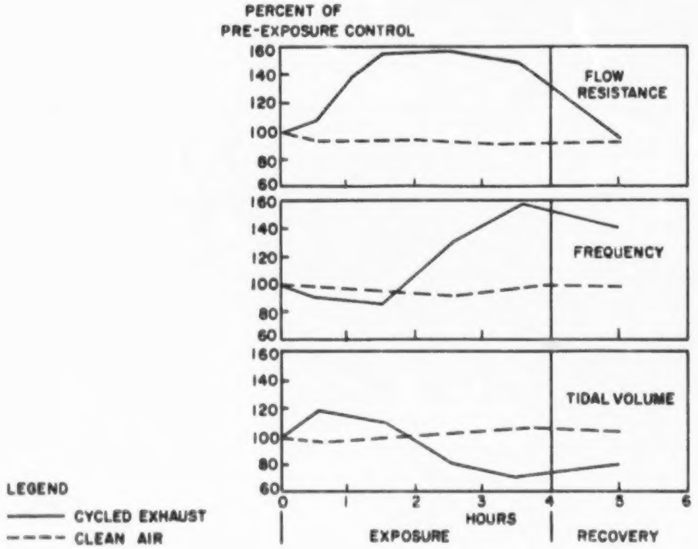

Figure 3-14. Guinea Pig Respiration During Exposure to Irradiated Exhaust or Clean Air

A FIRST ALERT would also be called under one of the following conditions, plus reasonable assurance of stagnant weather for an additional 24 hours.

SO_2 Concentration	Time
0.6 ppm	5 hours
0.75 ppm	4 hours
1.0 ppm	3 hours

3.5.3 SECOND ALERT

If concentrations reach the following values for the time period shown while on FIRST ALERT status, a SECOND ALERT would be recommended.

SECOND ALERT

Parameter	Concentration	Time
SO_2	0.75 ppm	4 hours
CO	35 ppm	4 hours
Soiling	7.0 COHS	4 hours

A SECOND ALERT would be called for any two of the above or any of those shown below, with reasonable assurance of stagnant weather for an additional 12 hours:

Parameter	Concentration	Time
SO_2	1.5 ppm	2 hours
CO	50 ppm	2 hours
Soiling	9.0 COHS	2 hours

3.5.4 MONITORING CONTAMINANTS

Monitoring of contaminants other than those required for current alert criteria is desirable. The New York City Department of Air Resources will soon be sampling 12 trace minerals in addition to the more common air pollutants. These elements are: arsenic, cadmium, vanadium, beryllium, cobalt, lead, manganese, chromium, iron, nickel, zinc and copper. The first six are known toxicants, and all are found in the local atmosphere. The major reason for the program is to provide base-line information should these elements be shown to be significant in the future. Monitoring metals is also useful for identification of emission sources.

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4.0 TECHNICAL DISCUSSION

4.1 INTRODUCTION

The formulation, implementation and execution of an Emergency Action Plan requires technical information in a wide variety of disciplines principally meteorology, air pollution engineering, chemistry, law, medicine, government, urban management, and administration. In this section of the manual, general background information will be presented that is important to episode avoidance planning.

4.2 SOURCE INVENTORY

4.2.1 INTRODUCTION

A source inventory for episode avoidance purposes varies only slightly from the inventory which would be conducted for "chronic" air pollution control purposes. The difference lies mainly in cataloguing the measures available to reduce emissions temporarily when necessary; the emphasis here is on these emergency control measures.

One clear method of reducing emissions during periods of high air pollution potential is to curtail or adjust the greatest contributors. In some instances. a significant reduction can be made by changing from high to low-sulfur fuels, if sulfur dioxide is a major problem.component. This may be of little use if automobile exhaust or particulates from a large number of point sources are the main elements to be controlled. An inventory of important emission sources is necessary; this can be accomplished in two stages:

(a) Gross pattern of emission sources, determined from a "paper" survey of the major sources plus "emission factor" calculations.

(b) Inventory of individual emission sources, determined by some degree of contact with each source (Questionnaire, visitation, stack sampling). This may be coupled effectively with a permit system calling for agency approval of all combustion and process equipment (Ref. 4-1).

These are discussed in the following sections: 4.3.2 and 4.3.3. Later sections emphasize emergency source control data, the display of information, and the important task of maintaining an updated emission inventory.

4.2.2 GROSS PATTERN OF EMISSION SOURCES

The "bench mark" references for determining the gross pattern of emission sources are: Rapid Survey Technique (PHS Pub. No. 999-AP-29); and Compilation of Air Pollutant Emission Factors (PHS Pub. No. 999-AP-42). For these purposes, sources are considered in these groups:

(a) Fuel combustion in stationary sources,
(b) Combustion of refuse material,
(c) Transportation,
(d) Industrial processes.

4.2.2.1 Fuel Combustion in Stationary Sources

These sources should be classified by type of user, type of emission source, quantity consumed, and geographical location. Figure 4-1 illustrates these classifications schematically. Ozalins and Smith (Ref. 4-2) presents details of gathering and processing fuel use and other data. A listing of sources of such data includes:

(a) U. S. Bureau of Census,
(b) U. S. Bureau of Mines,
(c) National Coal Association,
(d) State (fuel) associations,
(e) American Petroleum Institute,
(f) State petroleum marketing associations,
(g) Local utilities,
(h) Suppliers of fossil fuels,
(i) Large-volume fossil fuel users.

Competition among local distributors of fuel oil or coal may complicate data collection; the suppliers will probably provide the general information required, however. Chemical analyses (for sulfur and ash content) are not always readily obtained, except from large-volume users.

Because of the importance of power production as a potential source of air pollutants, this publication is specially cited:

> "Steam Electric Plant Factors," published annually by the National Coal Association, 1130 17th Street, N.W., Washington, D. C. $5.00.

Coal, oil and gas usage at power plants over the United States is tabulated, with many other useful data.

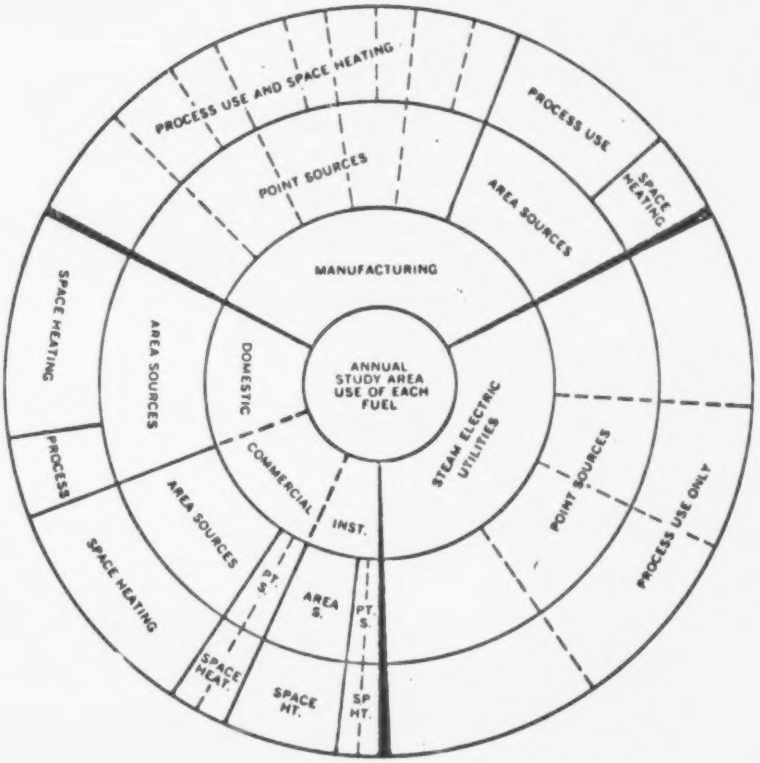

ANNUAL STUDY AREA USE OF EACH FUEL
MANUFACTURING
POINT SOURCES
PROCESS USE AND SPACE HEATING
AREA SOURCES
PROCESS USE
SPACE HEATING
DOMESTIC
AREA SOURCES
SPACE HEATING
PROCESS
COMMERCIAL
AREA SOURCES
SPACE HEATING
PT. S.
SPACE HEAT.
INST.
AREA S.
SPACE HT.
PT. S.
SP HT.
STEAM ELECTRIC UTILITIES
POINT SOURCES
PROCESS USE ONLY

Figure 4-1. Subdivision of Total Fuel Use by User Categories and Type of Use

The National Air Pollution Control Administration has prepared inventories for several U. S. Cities; personnel in the Air Quality and Emission Data Branch are available for advice and consultation to agencies responsible for air quality control.

4.2.2.2 Combustion of Refuse

Disposal of refuse has been accomplished by burning throughout history. Air pollution regulations in states and cities have been a major factor in reducing open burning; the use of public and private incinerators has increased, and unit design has been improved steadily.

The nature and amount of refuse generated have changed noticeably in recent years. The increased use of paper in packaging material and the wide use of plastics has resulted in an increase in the amount of refuse generated per capita and in the heating value of the refuse.

For the gross inventory, haulage--municipal or private--is a basis for estimating quantity of refuse. If open burning and backyard incinerators are used, a current factor may be obtained from the National Center for Urban and Industrial Health, U. S. Public Health Service, or from the Committee on Refuse Disposal of the American Public Works Association.

Incinerator operating records will show the periods of operation and quantities of refuse burned. Incinerators vary widely in the release of particulates, and general information on the age and performance of units is desirable.

4.2.2.3 Transportation

Transportation--or mobil--sources of air pollution include automobiles, buses, locomotives, trucks, ships and airplanes. Of these, automobiles, buses and trucks are most important to general community pollution.

Automobile emissions may be based on gasoline sales in the study area, since the gasoline is mostly consumed there. Diesel-fueled traffic, which is estimated to be less than 2% of the total traffic in a community (Figure 4-1), is mostly of the long-haul type; estimates are based on mileage and traffic flow.

Gasoline consumption estimates utilize these three items:

(a) Total annual sales of gasoline in the study area;

(b) Traffic-flow maps, showing traffic counts;

(c) Estimates of seasonal variation in traffic flow.

Sources of gasoline sales data are:

(a) State petroleum marketers associations;

(b) "Petroleum Facts and Figures," published by the American Petroleum Institute;

(c) "Retail Trade," published by the U. S. Bureau of Census.

Diesel fuel usage by buses is obtainable from local transit companies. Long-haul trucking information is available from:

(a) The local traffic control agency;

(b) The state highway department;

(c) State or national trucking associations.

4.2.2.4 Industrial Process Emissions

Ozalins and Smith (Ref. 4-2) list the following procedure for a rapid gross survey of industrial process emissions:

(a) Note the name and location of the processes that are to be considered. This tabulation can be facilitated by the use of the Directory of Manufacturers, which lists the companies by industrial classification. Employment data given in this publication may be used to pinpoint the large sources.

(b) Obtain production data (annual and average daily) and the efficiency of control equipment, if any, from each of the selected concerns.

(c) Calculate the emission rates by applying emission factors to the production data.

(d) Assign the average daily emission rates to the respective reporting zones.

Detailed knowledge of these sources is difficult to obtain; see section 4.2.3.4 for additional information.

4.2.3 INVENTORY OF INDIVIDUAL EMISSION SOURCES

For a completely satisfactory analysis of either chronic or episodic air pollution problems, these elements represent the ideal in information and capability:

(a) Knowledge of the pollutant emission rates from all sources, including their variations with time and the costs of control.

(b) Knowledge of the net result of atmospheric transport of pollutants to the receptors.

(c) Knowledge of the effects of pollutants in quantifiable terms.

Unfortunately, none of these ideal elements is yet available; in the practical world, it is necessary to tailor requirements and budgets proportionally to the problem, and to approach these "ideals" accordingly.

Pollutant emission rates from individual sources may require large expenditures. The techniques available are:

(a) Questionnaires

(b) Visitation and consultation,

(c) Emission source sampling.

Identification of those individual sources to be inventoried will result from the rapid or gross survey. All three techniques will probably be used in large cities or regions.

A permit system calling for review by the agency's department of all combustion and process equipment is an extremely strong tool for developing and maintaining a source inventory (Ref. 4-1). Also, the records of other municipal departments, such as the Building Department, and of specially Federally supported studies (as Urban Planning) have been used; a minor programming adjustment to make the records compatible can add significantly to the agency's emission inventory background data.

4.2.3.1 Questionnaires

A separate questionnair (or redesigned questionnaires) will be required to obtain information necessary for episode avoidance planning. The elements to be covered for these purposes are:

(a) Dual fuel capability

(1) Advance notice desired,
(2) Normal fuel, ash and sulfur content,
(3) Alternate fuel, ash and sulfur content,
(4) Time required to switch fuel,

(5) Seasonal availability of alternate fuel,
(6) Added (or reduced) costs of dual fuel capability (capital and operating costs);

(b) Process curtailment data

(1) Advance notice required,
(2) Emission time-history during curtailment,
(3) Emission rate after curtailment,
(4) Desirable curtailment time,
(5) Minimum curtailment time (for "high" alerts),
(6) Number of employees released on curtailment,
(7) Curtailment period allowable without substantial loss,
(8) Time after which curtailment imposes serious (unrecoverable) economic burden,
(9) Estimated economic loss per day of curtailment.

Load shifting by power companies must be a cooperative effort; reliance must be placed on power system engineers to exploit the available alternatives at the time of the incident. Emergency control actions in general are treated in section 4.7.

4.2.3.2 Visitation and Consultation

Whether or not questionnaires are used, personal visits to large individual pollution sources are desirable to obtain physical data and to establish a cooperative working atmosphere with the control agency. Much more information can be collected during visitations than by questionnaires.

The physical data collected should anticipate the use of dispersion calculations; a sample list of "statistics" to be gathered follows:

(a) Location and property boundaries,
(b) Plant capacity, normal and maximum,
(c) Fuel usage by shift, month and season,
(d) Fuel type and composition, especially sulfur and ash content,
(e) Fuel heating value,
(f) Input material flow rates,
(g) Number of supervisory employees,
(h) Number of hourly employees (this estimates the "auto population," a possible factor in curtailment planning),
(i) Number and frequencies of operating levels, if process is continuous,
(j) Number and frequencies of "batches" if process is "batch,"
(k) Source emission height and stack diameter,
(l) Emission rate of pollutants per unit of input material, including variation (mean and standard deviation),

(m) Particle size distribution of particulate emissions,

(n) Emission gas flow rates and temperatures including variation,

(o) Individual to be contacted on air pollution matters and telephone numbers,

(p) Emission curtailment information (see 4.2.3.1),

(q) Type, age and cost of pollution control equipment,

(r) Plans for expansion,

(s) Process flow diagrams,

(t) Interruptability of batch processes,

(u) Observations of settled dust,

(v) Observations of ventilation and hooding effectiveness,

(w) Observations of odors,

(x) Observations of housekeeping, as an indication of general maintenance.

The calculations to be made to convert the collected (numerical) statistics to emissions are straightforward engineering. Additional information is provided in section 4.2.4 (Emergency Source Control Data).

4.2.3.3 Source Sampling

The techniques of source sampling are fairly well documented (Ref. 4-3 through 4-11). Some regulations require that certain sources be monitored periodically or continuously by the emitter; this is the case for SO_2 from sulfuric acid plants in New Jersey, for instance. Other regulations (Cleveland, Ohio) require a "test by a disinterested third party," on request by the air pollution control authority, again at the cost of the emitter. In most large cities, some source sampling capability has been developed by the control authority, and is used for these purposes:

(a) To validate operating permits,

(b) To establish emission factors,

(c) To test compliance with emission codes.

For carrying out episode avoidance plans, source sampling may be desirable or required for these purposes:

(a) To determine emissions under other than normal operating conditions; it is a difficult task to obtain "normal" emission data, and opportunities to sample under abnormal conditions are few;

(b) To test for compliance with curtailment plans.

Very few sources can be sampled during an actual episode because of the short time available; even so, "spot" checking is a useful measure. More promising for these purposes is "remote sensing," and a discussion of some recent developments appears in Section 4.4.2.

Automated in-stack monitoring is difficult because of the robust environment to which the sensing element is exposed. Absorption of ultraviolet and infrared energy is potentially applicable for sulfur dioxide and other gases; changes in optical density of a gas stream can be used to determine particulate loading. A number of such devices have been announced (References 4-12 through 4-19).

4.2.4 EMERGENCY SOURCE CURTAILMENT DATA

4.2.4.1 Introduction

Reducing pollutant emissions as a measure to avoid potential episodes requires data not ordinarily obtained in the conduct of a "chronic" air pollution program. The available measures are as diverse as the sources, but subdivide generally into five classes.

(a) Switch to a low sulfur fuel (to reduce SO_2).
(b) Shift power loading.
(c) Curtail production operations.
(d) Postpone operations.
(e) Request voluntary traffic reduction.
(f) Cease all non-essential activities.

The required data can be described for the first class; for load shifting, curtailment of production and postponement of operation, it is desirable to develop close and knowledgeable contact with subject sources. It is not difficult to obtain legal authority to take extreme action in extreme emergencies; it is quite another matter to achieve degrees of curtailment in proportion to the "degree of emergency," with the possible exception of fuel switching and postponement of refuse combustion. These two measures may be entirely adequate in some areas, but of little use in high oxidant atmospheres such as Los Angeles and San Francisco.

4.2.4.2 Dual Fuel Capability (Fuel Switching)

During the inventory of individual emission sources, dual fuel capability, or provision for temporary use of a lower sulfur fuel, will probably have to be determined separately for each source. Power production is the largest single fuel consumer in a given area, ordinarily. Industries of all kinds use fuel for both space and process heating and may have dual fuel capability.

Whether a source is equipped to switch fuels now depends on economic advantage to the source, or on "chronic" air pollution regulations. The extra operating cost of burning low sulfur coal or oil is now between 10 and 25% more than that of using lower grades; the cost differential may decrease, and will be related to the market value of sulfur. This cost is not an obstacle for the avoidance of air pollution episodes. Switching from oil or coal to gas may be an economic advantage, however, and therefore independent of regulations, except for timing that may result from emergency requirements such as potential episodes.

4.2.4.2.1 General. There are some considerations on which background information will need to be gathered for emission sources in any given area. These are:

(a) Availability of substitute fuels
  (1) relative scarcity of alternate fuels,
  (2) competitive demands,
  (3) transportation costs;

(b) Availability of storage
  (1) space requirements,
  (2) handling facilities,
  (3) turn-over of stockpile;

(c) Technical features
  (1) alternate burners,
  (2) ash compatability,
  (3) particular emissions,
  (4) auxilliary equipment (heaters, pumps).

Fuel users are ready sources for this information.

The combinations available for fuel switching are shown in Table 4-1:

TABLE 4-1. COMBINATIONS AVAILABLE FOR FUEL SWITCHING

Primary Fuel	Low-Sulfur Coal	Low-Sulfur Oil	Gas
High-Sulfur Coal	X	X	X
High-Sulfur Oil		X	X

4.2.4.2.2 Low-sulfur Coal. Coal contains from about 0.4 to 10% sulfur; that having 1 percent or less is classified as low-sulfur. The average sulfur content for coal used in the United States is about 2.4 percent. Most of the high sulfur coal is consumed by the power industry. Most anthracite and some bituminous coals have low sulfur content. The sulfur in coal may be pyritic, organic or as sulfate. Sulfate is usually a minor form; pyritic may be removed mechanically (but not necessarily economically) while organic sulfur usually appears as SO_2 in the flue gas.

The steel industry is a strong competitor for the limited supplies of low sulfur coal. Combined with its lower natural occurrence, this makes low-sulfur coal more costly than high-sulfur coal. Depending upon the geographical location of the consumer relative to the high and low sulfur coal sources, transportation charges can alter the cost differential resulting from competition.

The cost of storing low-sulfur coal will be primarily the interest and taxes on the land and the losses due to weathering of the coal, assuming the stockpile is located so that the normally used handling equipment can service it. The stock should be turned over periodically, i.e., used and replaced, when episodes have not occurred.

The substitution of low-sulfur coal imposes two potentially significant technical problems: ash and particulate handling. Low-sulfur coals often have high ash fusion temperatures. So-called wet-bottom furnaces are designed to discharge the ash as a molten stream. If the ash fusion temperature is too high (above about 2600°F.), (Reference 4-20), the ash may pile up as a semi-fused or solid mass in the furnace bottom which will force the plant to shut down in 12 to 18 hours and can cause extensive damage to the furnace. High-sulfur coals provide a good electrolyte in the flue gas so that the resistivity of the fly ash is relatively low. If the plant has electrostatic precipitators designed for low-resistivity fly ash, a change to low-sulfur coal may result in increasing significantly the particulate emission due to lower collection efficiency. If switching to low-sulfur coal is to be the emergency control action, it may be necessary to modify the particulate control devices by adding more precipitators or by installing a mechanical separator in series with the electrical precipitators, or to arrange to decrease the flue gas temperature (and hence increase SO_3 absorption by the precipitated dust) to compensate for the reduced resistivity during the episode. A 10 or 15°F. change is significant. On the other hand, an increase in flue gas temperature, while not economical as a chronic control measure, has the effect of increasing the effective stack height which, if it penetrates the base of the inversion, may discharge the gases outside the stagnant region, depending on stack height and the height of the inversion. This effect is not well-established. Increasing the stack temperature by bypassing the air heaters would require a plant modification. The tradeoffs should be examined by experienced power plant engineers for the specific case at hand.

4.2.4.2.3 The Use of Low-Sulfur Oil or Gas. As indicated in Table 4-1, plants that are normally either coal-fired or oil-fired can conceivably switch to low-sulfur oil or gas.

Natural gas is practically sulfur-free. Oil, however, may contain sulfur. During the refinery processes, sulfur tends to be concentrated in the heavier residual fractions. Sulfur content of oils may be specified as follows (Reference 4-27):

GRADE	TYPE	MAXIMUM % SULFUR	
1	Distillate	0.05	
2	Distillate	0.10	
4	Residual	no limit specified	
5	Residual	no limit specified	Range is 0.34 to 4.0 average about 1.6%
6	Residual	no limit specified	

Distillate oils are normally used for residential heating and industrially in heat treatment and non-ferrous, glass and ceramic furnaces, while the residuals are used in large space heaters and industrial furnaces.

Local availability of low-sulfur oil and gas is more a question of location with respect to source and the means of transportation than one of inherent scarcity. With advances in the technology of desulfurization, low-sulfur oil is likely to be more plentiful. Oil, like coal, may be stockpiled for use during an episode. Storage costs will be incurred. At the well, gas compares favorably with other fuels on a cost per unit heat content. Away from the well, gas requires sufficient pipe-line facilities into the area to handle the whole demand. Consequently, in localities distant from the gas fields, the use of gas as a dependable dual fuel may not be practical. Its availability must be determined locally.

The substitution of low-sulfur oil or gas for other fuels normally requires the provision of special burners. This is obvious for normally coal-fired furnaces. For normally oil-fired furnaces, the fuel handling equipment, including heaters, and the burners are designed for high viscosity residual oils rather than for low viscosity distillate oils or gases. In addition, the ignition characteristics and safety features of the furnace must be compatible with the substitute fuel; serious explosions can occur in a furnace with improperly operated burners.

The feasibility of substituting low-sulfur oil for high sulfur coal should be examined by experienced plant engineers for each specific situation. In addition to differences in burners and auxilliary equipment the impact on particulate emissions should be examined where electrostatic precipitators are used. (See above under low-sulfur coal).

4.2.4.2.4, "Combination Actions. For power systems, complete shut-down is generally impractical since electric power is required for the public health and safety. The local situation may, however, permit some steam generating plants to either shut-down or curtail their outputs if the balance of the connected system can pick up the load with plants that can switch fuels or which do not contribute to air pollution in the episodal area. Load shedding is a complex system-wide procedure involving a continuous equalization of generation and load (Reference 4-21). As a result of the Northeast blackout in 1965, load-shedding by portions of a power system is now a generally accepted procedure during crises. Since the capacity to shift load is very sensitive to the geographical extent of the episode, this emergency action will require interregional coordination as well as detailed engineering by the power systems technical staff.

For other industries, it may be possible to combine curtailment and fuel substitution by providing substitute fuel to only those elements of the industry which are technically difficult or otherwise impractical to shut-down or curtail.

4.2.4.3 General Data for Curtailment Plans

Each source may be required to submit or to have available for inspection curtailment plans showing those data detailed in Section 4.2.3, plus the operational changes to be made in curtailing emissions. General information to be included in these plans is discussed below.

4.2.4.3.1 Time-Histories of Pollutant Emissions. The "time-history" of a variable is merely a record of the variable with time. See Figure 4-2.

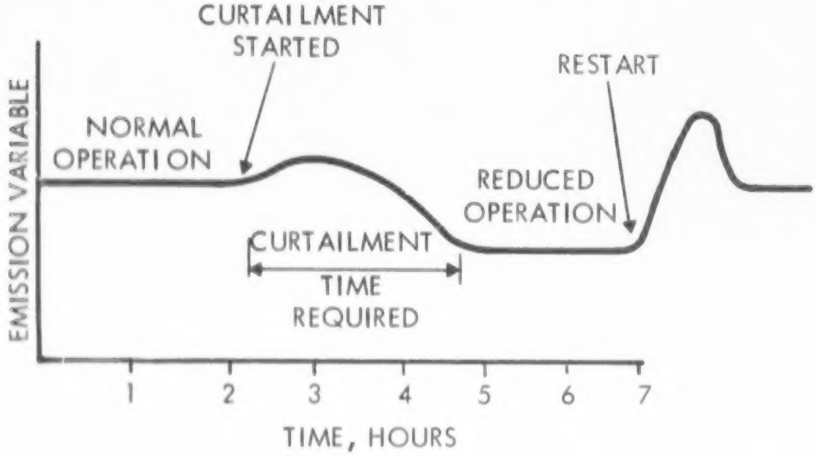


Figure 4-2. Time-History of Pollutant Emissions

In planning the curtailment of emissions of a given pollutant, it is desirable to know the change in total emissions with time, for these reasons:

(a) Curtailment causes some emissions to increase temporarily;

(b) The time to achieve a reduction in concentrations will be important for future planning;

(c) Emissions during restart may influence the decision to curtail.

The preparation of curves summing the total emissions against time in a community will of course depend on cumulating individual source emissions. This will be difficult at the present time, because emissions under changing operational conditions are not known. Estimates provided by individual sources, based on knowledge of the operations, can be obtained during the inventory process or as a part of a permit system. Better yet, curtailment emission estimates may be required by regulation in individual Curtailment Plans.

The time required for curtailment may be the most useful data produced from time-histories. In the absence of even estimated emissions during curtailment, the time required can always be estimated; even if emissions rise before descending to a new reduced level. The effect may not be severe if the time period of elevated emissions is brief. The summing and display of these data are best done by computer, where the number of sources is large.

4.2.4.3.2 Advance Notice Required. The advance notice needed by emitters subject to curtailment may vary from an hour to several days. This information can be supplied only by persons with knowledge of the process and its relationship with other processes, either within or external to a given operation. Reduction of power plant output, for instance, depends on reduction of power demand. The advance notice desired and the details of notifying the affected sources are important parts of the total Emergency Action Plan. See Section 3.4.

4.2.4.3.3 Side Effects. There will be important side effect considerations in mose Curtailment Plans.

(a) Releasing employees at unusual times may be beneficial in spreading out traffic flow;

(b) Telephone switchboards may be overcrowded;

(c) The suppliers and customers of each emission source may be affected, and the Curtailment Plan for each source should anticipate such effects.

A listing of possible economic effects for business in general is provided in Section 4.6.2.

(a) Curtailment of Some Industry Groups

   (1) Power Generation. Power systems cannot be curtailed to the point of loss to public safety and welfare. Fuel-switching is likely to be the most significant curtailment activity; load shifting depends on the capability to redistribute loads in any given area.

   (2) High Temperature Continuous Process Industries. This class includes such activities as the operation of blast furnaces; the manufacture of glass; oil refining and other petrochemical operations; coking; acid manufacturing plants; calcining operations such as the manufacture of cement; some food processing operations; and many chemical manufacturing processes. Dual-fuel capability is highly desirable.

The two primary problems with the shutdown of any continuous process are to stop the process efficiently and to purge the system of in-process material. These problems are aggravated when the process involves high temperatures. Generally neither hot nor cold in-process material can be left in the furnace, oven, or reactor. Another problem is keeping the equipment in stand-by condition, since it may be severely damaged if allowed to cool. For example, blast furnaces and continuous glass furnaces are normally operated until their linings fail and cannot be allowed to go cold without severe economic loss.

Electrolytic processes such as aluminum and magnesium production incur severe damage if allowed to cool. The power load may be reduced temporarily; here is an example where emissions at various stages of curtailment may not be obtainable at the present time.

In refineries, in-process materials are often toxic or hazardous volatile liquids and gases. Refineries are designed with vapor disposal systems as safety features and to handle normal turn-around operations for various pieces of equipment. Because the refinery is such a close-coupled system, a complete shutdown in a technically difficult and perhaps unrealistic undertaking, particularly for a short-period transient situation.

4.2.4.3.4 High Temperature Batch Process Industries. This class includes such processes as the manufacture of steel in electric, open hearth, basic oxygen or Bessemer furnaces or converters; some primary non-ferrous and all secondary smelting; batch, glass manufacturing; paint and varnish manufacturing; and a multitude of chemical manufacturing processes. Dual-fuel capability is highly desirable.

In batch processing, the process is normally terminated at the completion of each batch. Consequently, the primary problem associated with shut-down is putting the equipment in stand-by condition. Batch processes vary in time per batch from a few minutes to many hours, perhaps as much as 36 to 48. Consequently, time is a significant consideration in shutdown plans involving batch process industries. The interruptability of a batch without severe economic loss may be important and should be included in the emission inventory.

4.2.4.3.5 Industries Processing Perishable Materials. This category includes many of the food processing industries, and others involving biological and active chemical systems. Processing or storage of photographic material, leather and electrical batteries, for example, could be included in this class.

There may be at one or more points in a process a possibility of spoilage or decay of the raw material, an intermediate product and/or the final product. In addition to causing economic loss, the spoilage could contribute to local air pollution. The situation can arise in a plant being shut-down without adjusting the flow of incoming raw material or making allowance for refuse disposal. Of course, only those operations contributing to air pollution will be directly curtailed, except when all "non-essential" activities are ceased.

4.2.4.3.6 Other Point-Sources. This category includes other industries which employ processes or unit operations not included in the above classes, such as materials handling, evaporation, crystallization, agitation, heat transfer and packaging. Dual-fuel capability, again, is highly desirable.

Some processes may be incidental to the primary purpose of the industry, yet be significant. An example is evaporation at points where large volumes of volatile materials are handled, such as petroleum loading-and-storage facilities and dry cleaning plants. Others of these processes may be "in-line" with processes that cannot be readily curtailed; a cooling tower emitting hydrocarbons must be phased with associated equipment; waste gases such as SO_2 supplied as raw materials to neighboring plants must be managed carefully.

4.2.4.3.7 Refuse Disposal. The incineration of solid waste by municipalities, individualoperations (lumber mills, construction, large apartment buildings) is usually coupled with fuel shifting as a control measure in early and later alert stages. The shutdown of individual home backyard burning offers no problem other than communication and enforcement. Open burnign dumps may be difficult to extinguish; these are being banned in most states.

The shutdown of incinerators can cuase increased emissions for a short time, and not of great significance. In all cases there will be the problem of accumulating raw waste, and of higher throughput following the period of curtailment.

4.2.4.3.8 Postponement of Operations. This is set out separately to highlight the fact that resourcefulness and cooperation can expose many possibilities for temporarily curtailing emissions. Pumping of water to elevated storage points often can be delayed a few days; road construction involving asphalt can be delayed; manufacture of expanded slag can be delayed. By ranking and contacting the users of power according to power consumed, the control agency can explore these alternatives.

4.2.4.4 Voluntary Curtailment

The public may be requested to help in reducing total automobile exhaust emissions; this is generally believed to be ineffective as a control measure. In extreme emergency conditions, it will probably be necessary to actually restrict traffic by executive order of the mayor or governor. This is the only episode avoidance measure contemplated in some cities at the present time.

The public can be requested to:

(a) Restrict unnecessary travel, use car pools where feasible.

(b) Reduce residential thermostats, avoid using unnecessary electrical power (restrict to 40 watts per room).

(c) Stay indoors and rest as much as possible.

(d) Very sensitive individuals consult their doctors.

The curtailment of major point sources may be planned to be implemented on a voluntary basis. Even so, the voluntary actions to be taken should be known to the control agency, and surveillance conducted as though the curtailment were mandatory. That is, all the elements in "Implementing an Emergency Action Plan" (Section 3.3) should be weighed and carried out to a degree appropriate to the problem. Experience to date with voluntary compliance by major emitters has been excellent. This indicates that pollution control is an easier matter in the "emergency" case than in the "chronic" case.

4.2.4.5 Cessation of Non-essential Activities

The chart presented in 4.7.1 shows possible control actions for various stages of emergency. The "third alert" stage is keyed to the cessation of all "non-essential" activities. This action may not be difficult to enforce for a single or even two days; for longer periods, the perturbation is likely to cause some genuine hardship, particularly to the wage earner not likely to recoup lost income.

During the emission inventory, a sampling of opinions of the probable consequences of extended high-alerts can be undertaken; opinion-surveying is reportedly full of pitfalls, mainly great error, and should be treated accordingly.

4.2.5 PROCESSING AND DISPLAY OF INFORMATION

4.2.5.1 Processing

Whatever methods of inventory, registration, and regulation are used for emission source "intelligence" the result will be a volume of data that requires continual sorting and evaluation. In the smaller urban areas, emission inventory data can be processed and analyzed manually by the staff; this continues to be entirely adequate in many areas. Maintaining an updated inventory is a continuing responsibility, and in a large, urban area can involve considerable expenditure of funds. Careful planning of an information processing and display system will help in realizing maximum benefit from the budget.

A large urban area will have thousands of sources. Manual processing and analysis is tedious and some analytical procedures may be next to impossible to perform manually in the time available. Computer systems for the storage, retrieval, processing and analysis of emission source data are being used more and more. The ingredients for such a system are as follows:

(a) Acquisition or access to a computer with both random and sequential access auxiliary storage facilities, so that filing and file maintenance can be accomplished rapidly and efficiently.

(b) Development of a coding system (Reference 4-22), preferably in cooperation with other urban agencies such as Planning and Housing, Urban Renewal, Building Permits and Inspection, Public Works, etc; some data requirements are common to all of these departments as well as to air pollution control. Coding parameters should include:

   (1) Pollution control equipment, cost, and performance.

   (2) Type of processing activity, and process rates.

   (3) Location of processing sites, keyed to (x,y) mapping coordinates.

   (4) Types of pollutants.

   (5) Qualities of pollutants and rates.

   (6) Stack heights; gas blow rates, temperatures and velocities.

   (7) Methods and results of curtailment at each alert stage.

   (8) Complaint Histories.

   (9) Fuel Use Information, rates and fuel-switching capability.

(c) Information retrieval programming so that any set of parameters may be retrieved from the files selectively. For example, the planner may wish to know the location of all plants using high-sulfur coal that emit an average daily concentration of SO_2 between 1 and 3 ppn, or from which dust-fall exceeds 100 tons per square mile per month. Once programmed, such operations are very inexpensive to operate.

(d) Analysis programming, so that emission source data may be evaluated and correlated to "ambient" exposures as desired. In the event a computerized "real time" (continuous, on line with the computer) monitoring system is used, source information can be correlated with monitoring data as an aid in making control decisions. There is promise of even developing models that are continually "self-adjusting," based on such feedback. (See Section 4.5.)

4.2.5.2 Display

With or without using computers, emission source information may be presented either in tabular or graphic form, depending upon the use to which it will be put. Fuel use information can be displayed as shown in Table 4-2, which indicates annual consumption by fuel and by consumer category; the amount for each consumer category is expressed in tons or gallons and also as percent of total for each category, giving the viewer absolute as well as relative information on the use of coal, oil and gas. Other examples of tabulated information are shown in Tables 4-3 and 4-4. Data of these types may also be represented effectively in bar or line graphs (Figure 4-3).

Another graphic approach to data display is the use of density maps, such as those shown in Figures 4-4 and 4-5, and location maps, like those shown in Figures 4-6 and 4-7. Maps such as these may be used to advantage in pin-pointing the location of present and potential problem areas when planning emergency control measures.

Density maps can also be produced by computer emission inventory data. Each source is identified by the (s,y) coordinates of the grid square in which it is located. The emissions for each grid square are averaged and a density symbol is assigned to the square according to the magnitude of the average. The printed output from the computer shows the grid square with the appropriate density symbol, the legend, and the title of the display, the map of the area is superimposed on the output by means of a transparent overlay. This technique is useful for evaluating the density changes that may be expected under the source reductions required for the various alert stages. An example of this graphic method is shown in Figures 4-8a and 4-8b.

Careful consideration should be given to the arrangement of data in tabular or graphic displays; it should be such that the important relationships among categories of information are easily seen and understood.

TABLE 4-2. ANNUAL FUEL CONSUMPTION IN INTERSTATE AIR POLLUTION STUDY AREA, 1963

Fuel	Consumer category	Annual consumption	Percent of total
Coal, tons/year	Industry[a]	1,628,000	21.8
	Steam-electric utilities	4,874,000	65.3
	Residential	738,000	9.9
	Other	222,000	3.0
	Total	7,462,000	100.0
Fuel oil--residual, gal/year	Industry	106,223,000	99.0
	Steam-electric utilities	642,000	0.5
	Residential	n[b]	n[b]
	Other	n[b]	n[b]
	Total	106,865,000	100.0
Fuel oil--distillate, gal/year	Industry	8,284,000	6.1
	Steam-electric utilities	0	0
	Residential	120,543,000	88.9
	Other	6,414,000	5.0
	Total	135,233,000	100.0
Gas, million cubic feet/year	Industry	68,151	51.8
	Steam-electric utilities	9,252	7.0
	Residential	51,078	38.9
	Other	2,974	2.3
	Total	131,454	100.0

[a] An additional 1,327,000 tons is used in the production of coke.
[b] n = Negligible.

TABLE 4-3. AIR POLLUTANT EMISSIONS FROM COMBUSTION OF FUELS IN STATIONARY SOURCES IN INTERSTATE AIR POLLUTION STUDY AREA

1963 (tons/year[a])

Fuel	User category	Aldehydes	B(a)P[a]	Carbon monoxide	Hydro-carbons	Nitrogen oxides	Sulfur oxides	Partic-ulates
Coal	Industrial	3	414	2,442	814	16,276	98,390	37,990
	Steam electric	11	7	1,220	487	51,261	244,443	22,400
	Residential	1	157	18,873	3,682	2,945	46,194	18,873
	Other	n[b]	31	3,587	714	571	13,800	5,450
	Totals	15	609	26,100	5,697	71,053	402,827	84,713
Fuel oil	Industrial	93	10	94	93	2,055	14,300	683
	Steam electric	n[b]	n[b]	n[b]	n[b]	41	31	n[b]
	Residential	113	n[b]	113	113	2,015	3,590	671
	Other	6	1	6	6	103	198	34
	Totals	212	11	213	212	4,214	18,119	1,388
Gas	Industrial	111	2	89	n[b]	5,376	15	423
	Steam electric	4	n[b]	n[b]	n[b]	1,793	3	68
	Residential	244	n[b]	74	244	2,935	9	354
	Other	20	1	5	20	210	n[b]	27
	Totals	379	3	168	264	10,314	27	872
	Grand totals	606	623	26,500	6,173	85,581	420,973	86,973

[a] Benzo(a)Pyrene in lb/year.

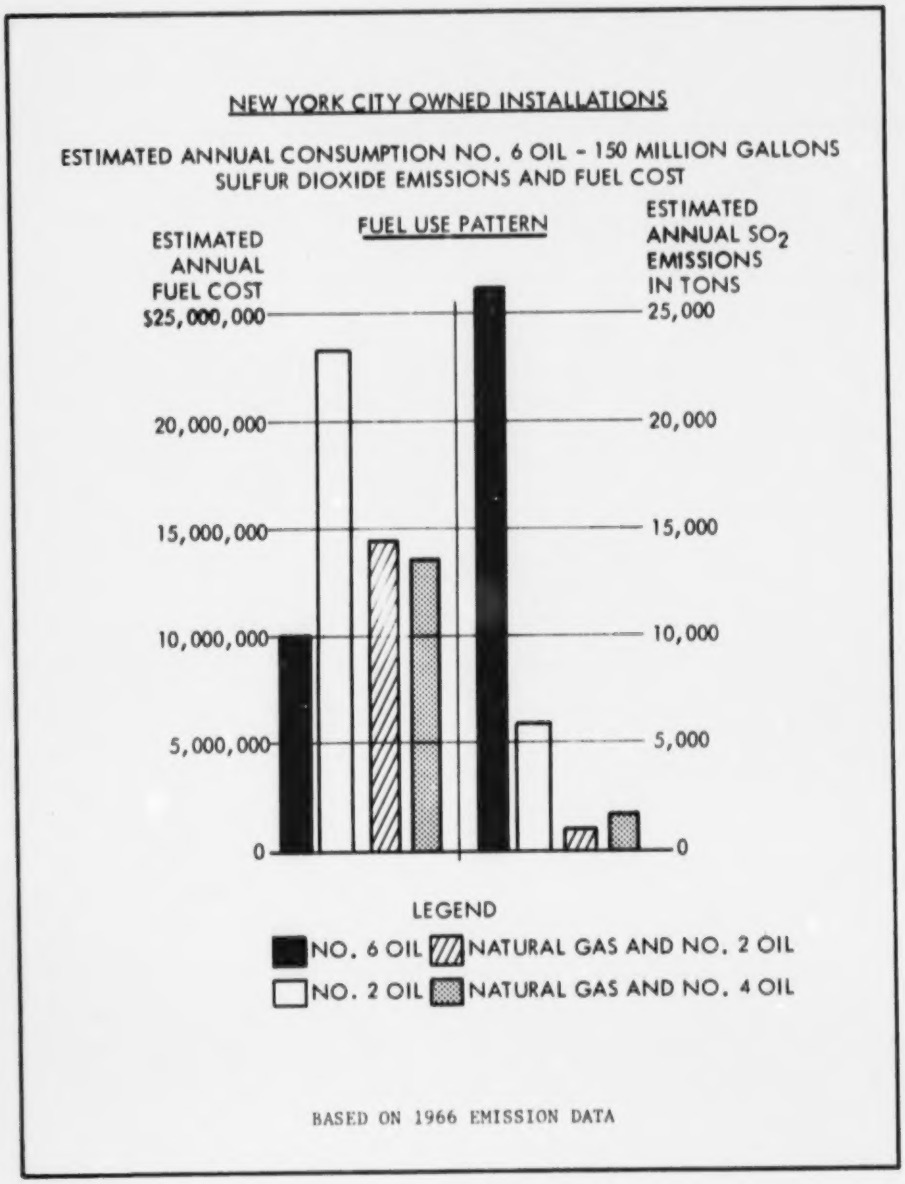
[b] n - Negligible.

TABLE 4-4. INDUSTRIAL COAL USE BY BURNER TYPE AND TYPE OF AIR POLLUTION CONTROL DEVICES USED IN INTERSTATE AIR POLLUTION STUDY AREA, 1963

	Air pollution control devices									
	No control devices		Settling chambers or water sprays		Cyclones or other inertial separators		Multiclones or ESP[b]		Total	
Type of firing equipment	Number of units[a]	Quantity of coal burned, tons/year	Number of units[a]	Quantity of coal burned, tons/year	Number of units[a]	Quantity of coal burned, tons/year	Number of units[a]	Quantity of coal burned, tons/year	Number of units[a]	Quantity of coal burned, tons/year
Underfeed stokers	13	21,000	5	2,400					18	23,400
Chain grate stokers	24	244,000	11	325,000	7	88,000			42	657,000
Traveling grate stokers	5	5,600	5	135,000	3	23,000			13	163,600
Hand-fired	12	4,000							12	4,000
Pulverized coal units					10	114,000	22	516,000	32	630,000
Spreader stokers with ash reinjection					3	35,000	1	50,000	4	85,000
Spreader stokers without ash reinjection	2	8,000	6	17,000	1	28,000	1	15,000	10	68,000
Totals	56	282,600	27	479,400	24	288,000	24	581,000	131	1,631,000
Percent of total	42.8	17.4	20.6	29.3	18.3	17.7	18.3	35.6	100	100

[a] The number of units given represents the number of boilers, not installations. An installation with two boilers is entered as 2.

[b] Electrostatic precipitators.

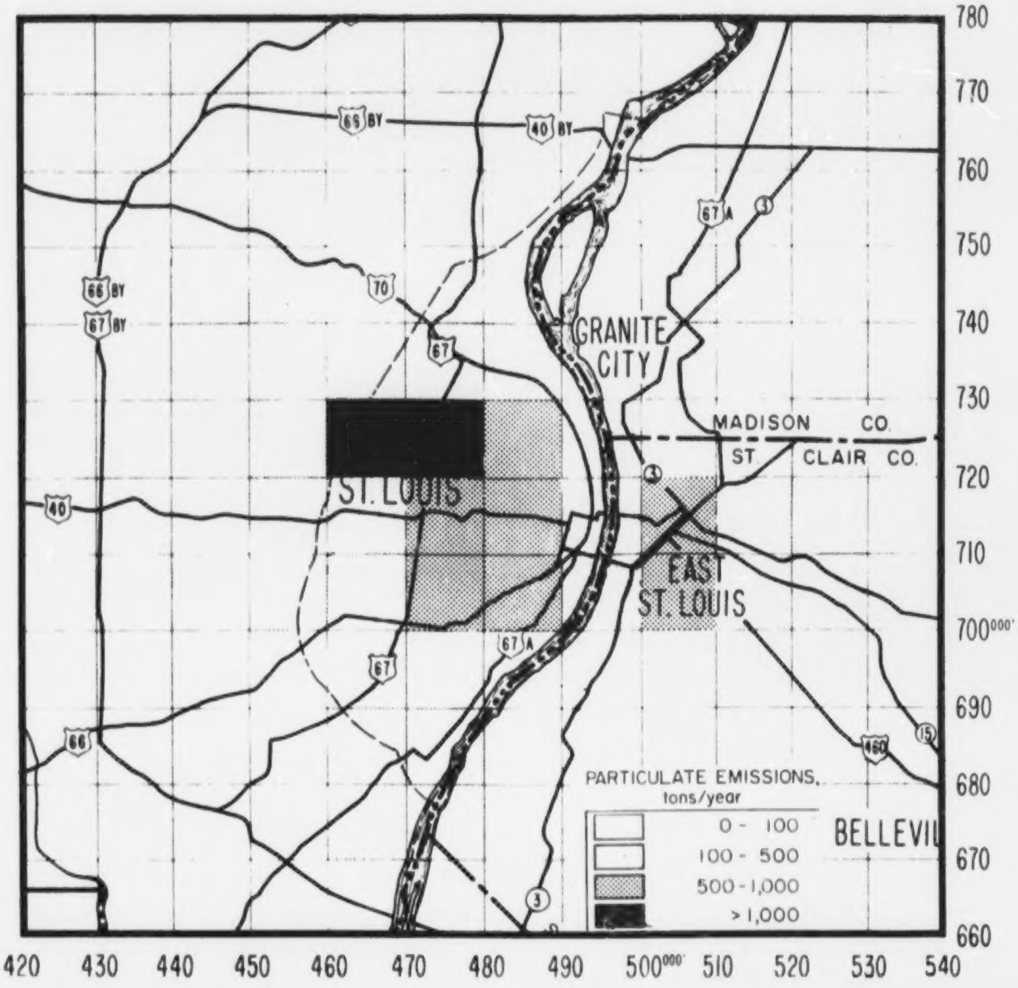


NEW YORK CITY OWNED INSTALLATIONS

ESTIMATED ANNUAL CONSUMPTION NO. 6 OIL - 150 MILLION GALLONS
SULFUR DIOXIDE EMISSIONS AND FUEL COST

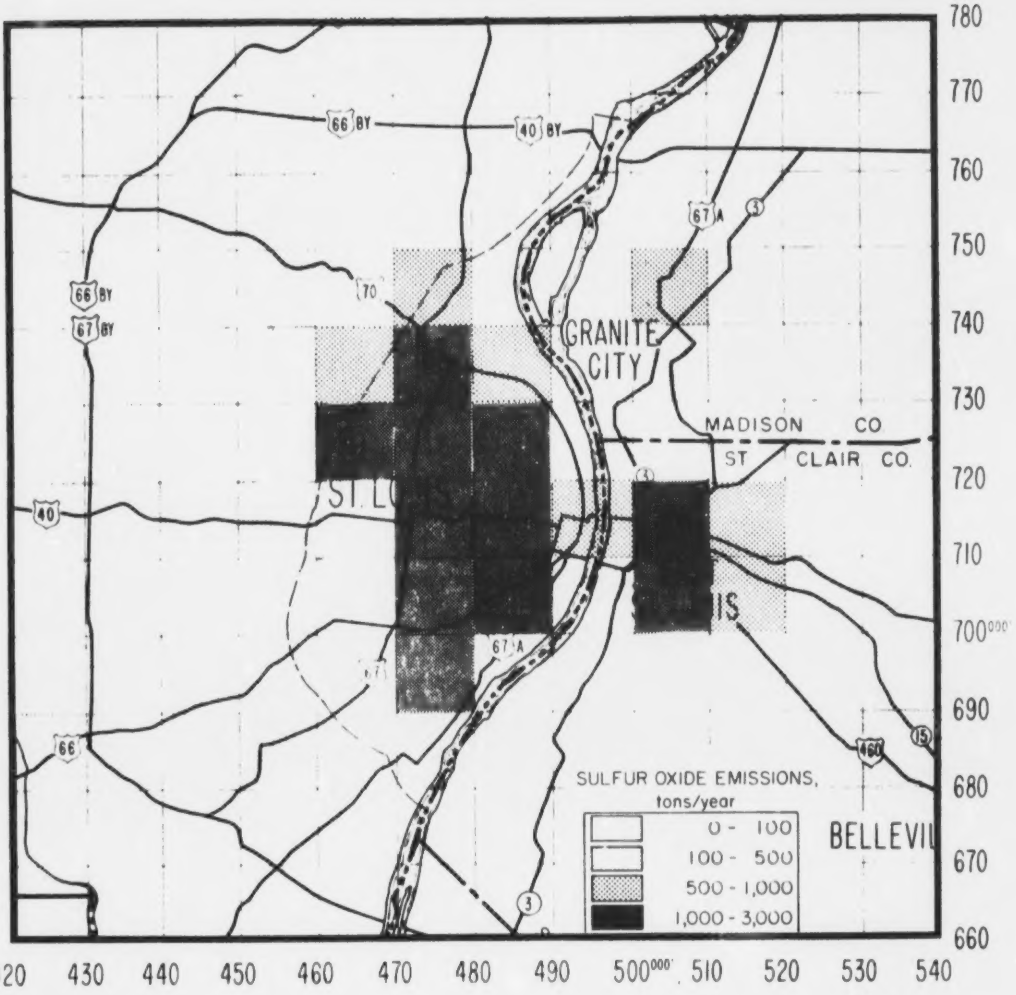
BASED ON 1966 EMISSION DATA

Figure 4-3. New York City Owned Installations



780
770
760
750
740
730
720
710
700000'
690
680
670
660
420
430
440
450
460
470
480
490
500000'
510
520
530
540
66 BY
40 BY
67 A
70
66 BY
67 BY
67
GRANITE CITY
MADISON CO.
ST CLAIR CO.
ST. LOUIS
40
EAST ST. LOUIS
67 A
67
66
460
15
3
PARTICULATE EMISSIONS, tons/year
0 - 100
100 - 500
500 - 1,000
> 1,000
BELLEVI

Figure 4-4. Emissions of Particulates from the Residential Use of Fuels


66 BY
40 BY
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70
66 BY
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GRANITE CITY
MADISON CO
ST CLAIR CO
ST. LO
40
IS
67 A
67
66
460
15
BELLEVIL
SULFUR OXIDE EMISSIONS, tons/year
0 - 100
100 - 500
500 - 1,000
1,000 - 3,000
780
770
760
750
740
730
720
710
700000
690
680
670
660
420
430
440
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500000
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520
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540

Figure 4-5. Emissions of Sulfur Oxides from the Residential Use of Fuels

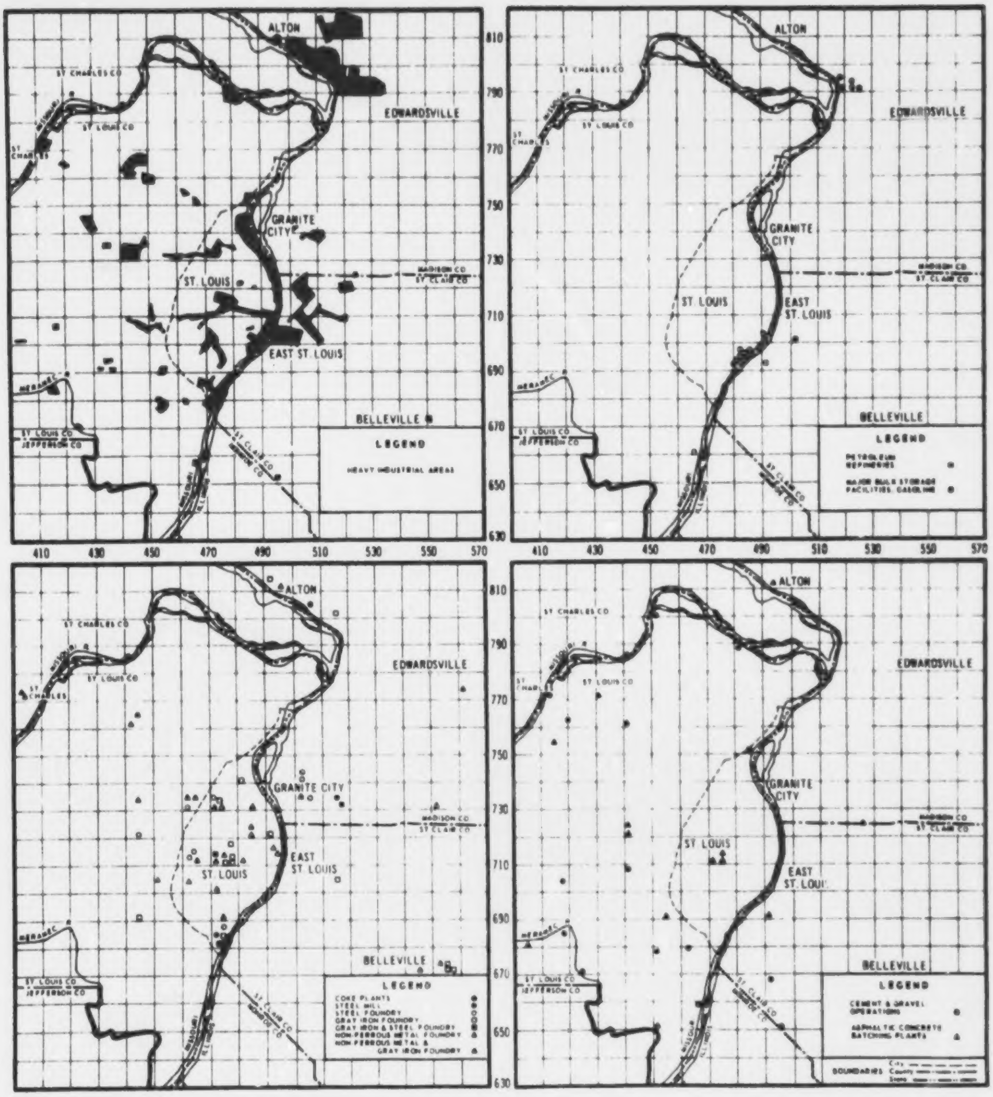
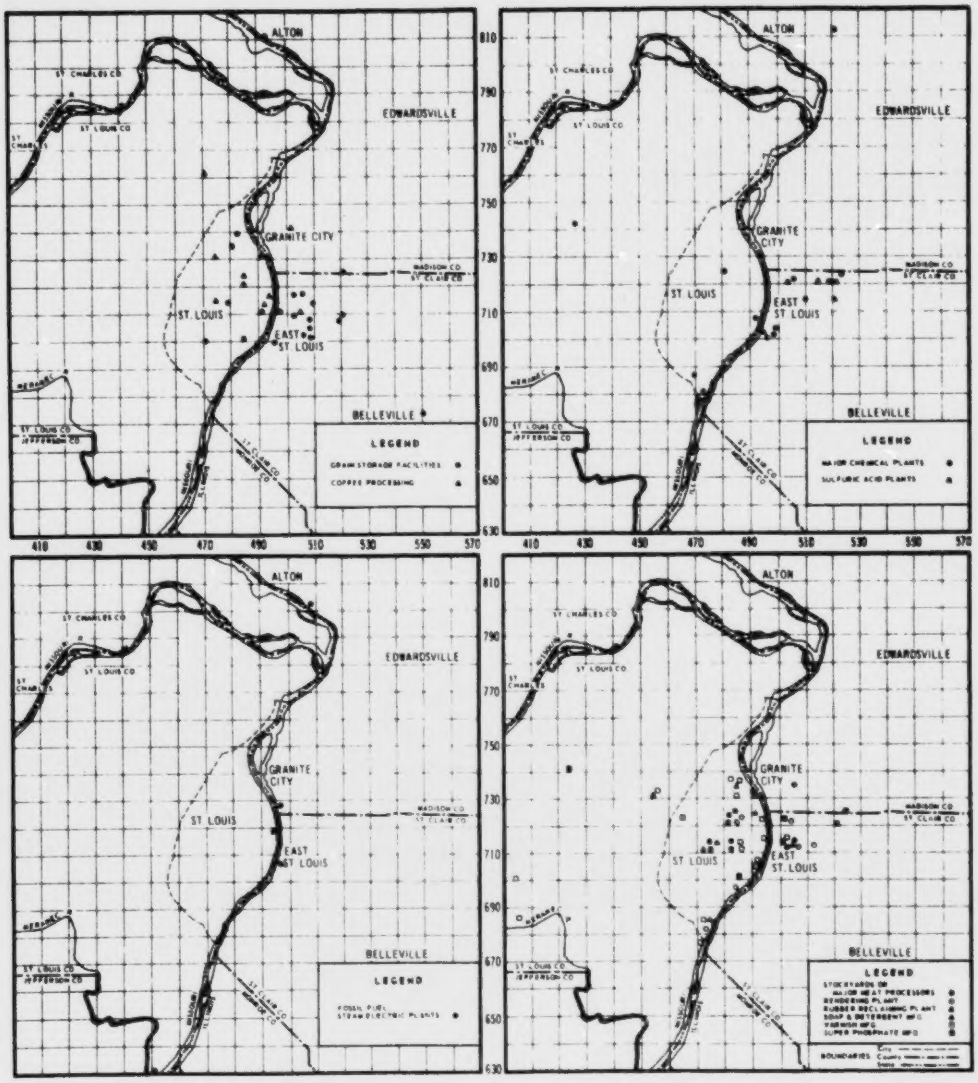

ALTON
ST CHARLES CO
ST LOUIS CO
ST CHARLES
EDWARDSVILLE
GRANITE CITY
ST. LOUIS
EAST ST. LOUIS
MADISON CO
ST CLAIR CO
MERAMEC
ST LOUIS CO
JEFFERSON CO
BELLEVILLE
MONROE CO
LEGEND
HEAVY INDUSTRIAL AREAS
PETROLEUM REFINERIES
MAJOR BULK STORAGE FACILITIES, GASOLINE
COKE PLANTS
STEEL MILL
STEEL FOUNDRY
GRAY IRON FOUNDRY
GRAY IRON & STEEL FOUNDRY
NON-FERROUS METAL FOUNDRY
NON-FERROUS METAL & GRAY IRON FOUNDRY
CEMENT & GRAVEL OPERATIONS
ASPHALTIC CONCRETE BATCHING PLANTS
BOUNDARIES City County State
810
790
770
750
730
710
690
670
650
630
410
430
450
470
490
510
530
550
570

Figure 4-6. Major Industrial Operations


ALTON
EDWARDSVILLE
ST CHARLES CO
ST LOUIS CO
ST CHARLES
GRANITE CITY
ST. LOUIS
EAST ST. LOUIS
MADISON CO
ST CLAIR CO
MERAMEC
ST LOUIS CO
JEFFERSON CO
MISSOURI
ILLINOIS
BELLEVILLE
LEGEND
GRAIN STORAGE FACILITIES ●
COFFEE PROCESSING ▲
MAJOR CHEMICAL PLANTS ●
SULFURIC ACID PLANTS ▲
FOSSIL FUEL STEAM ELECTRIC PLANTS ●
STOCKYARDS OR MAJOR MEAT PROCESSORS
RENDERING PLANT
RUBBER RECLAIMING PLANT
SOAP & DETERGENT MFG
VARNISH MFG
SUPER PHOSPHATE MFG
BOUNDARIES City County State
810
790
770
750
730
710
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630
410
430
450
470
490
510
530
550
570

Figure 4-7. Major Industrial Operations

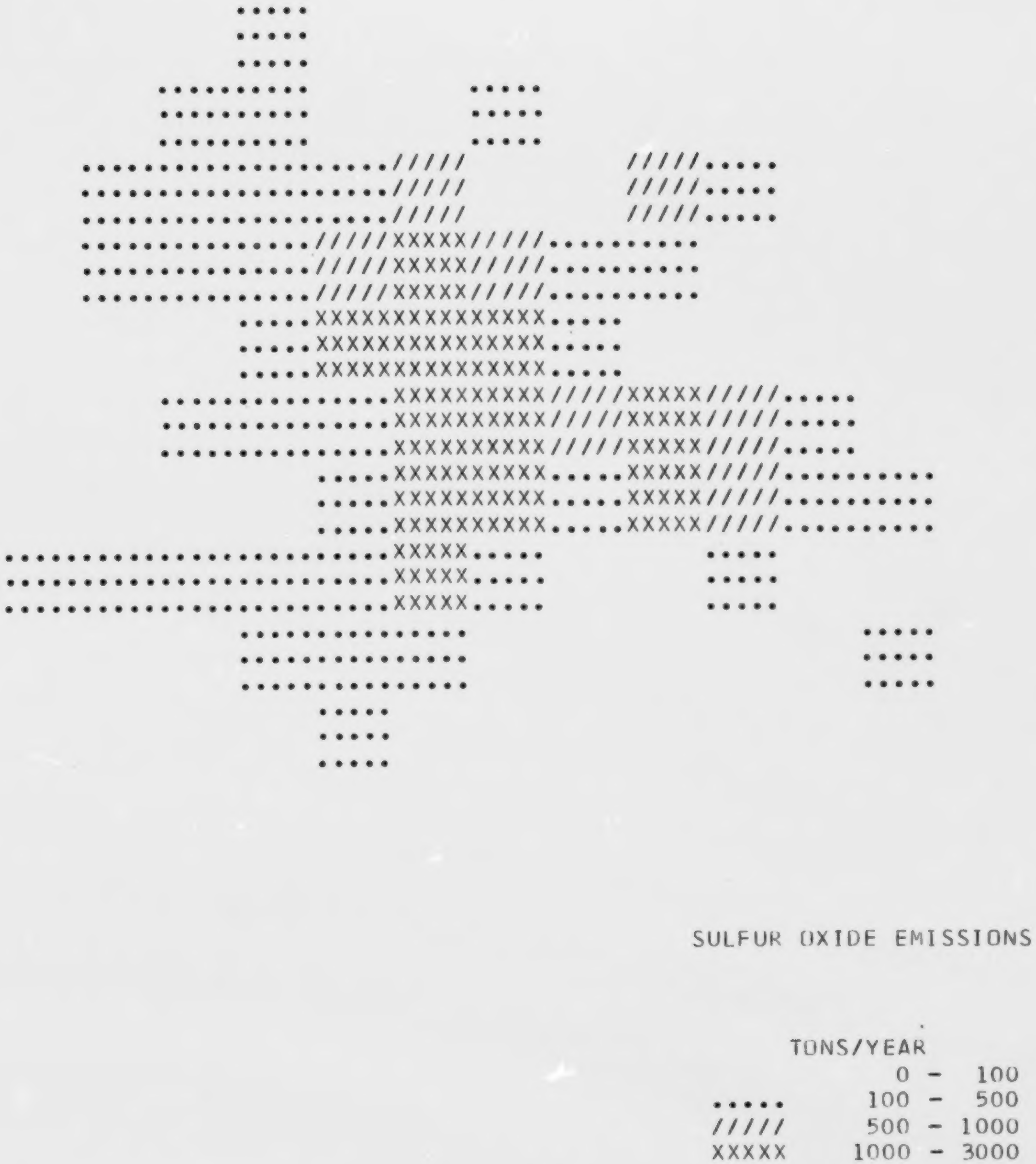
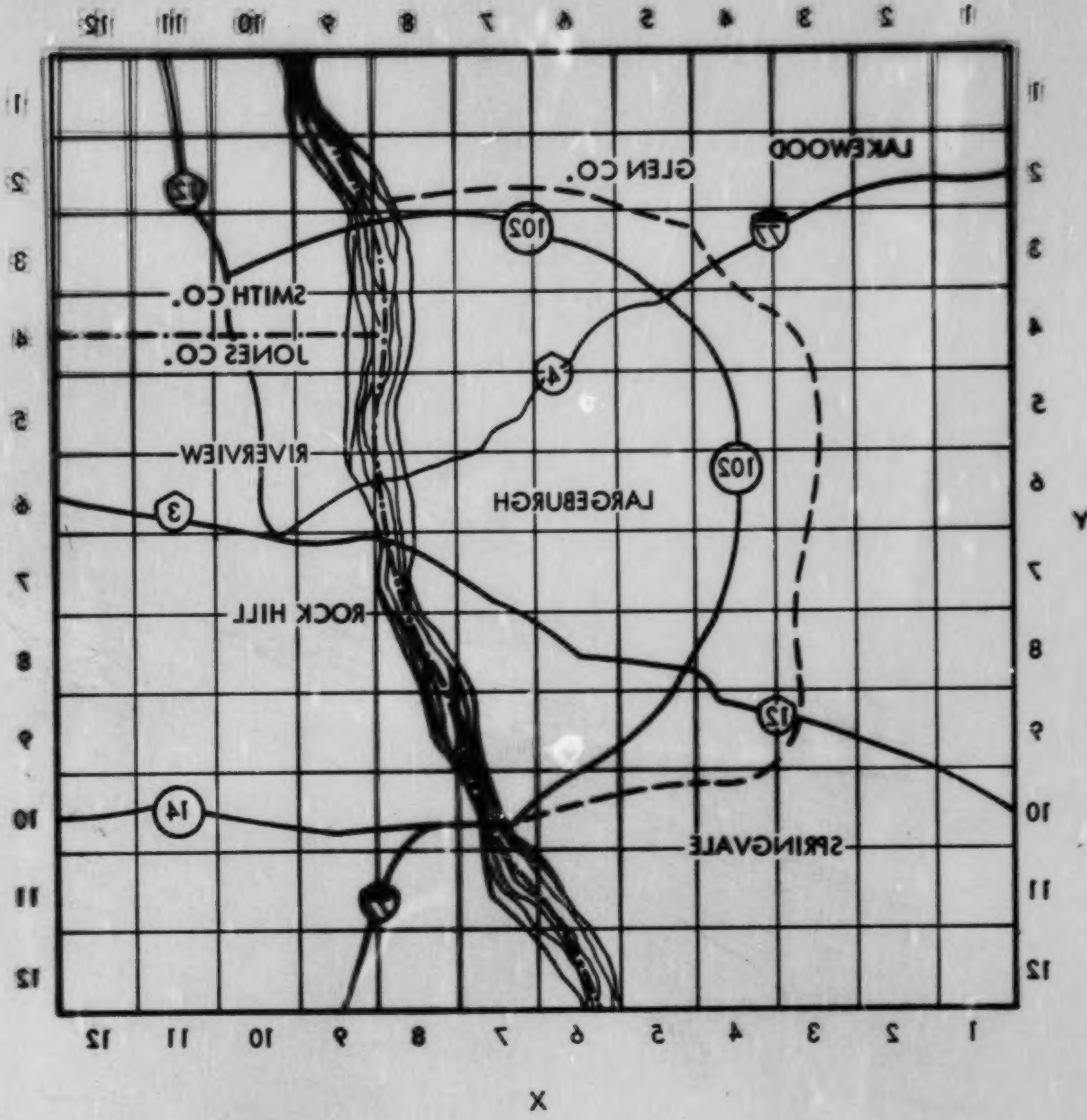
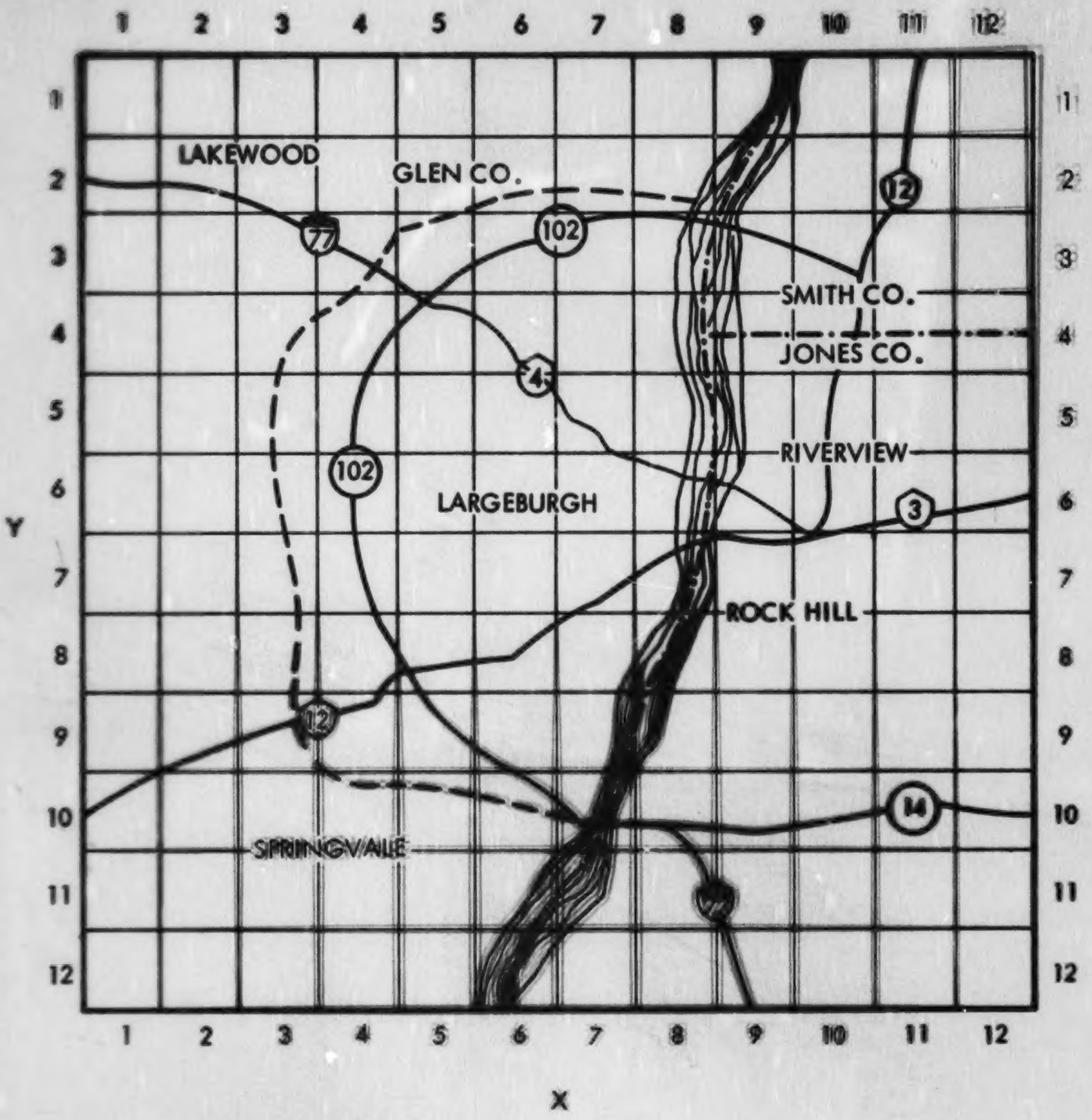
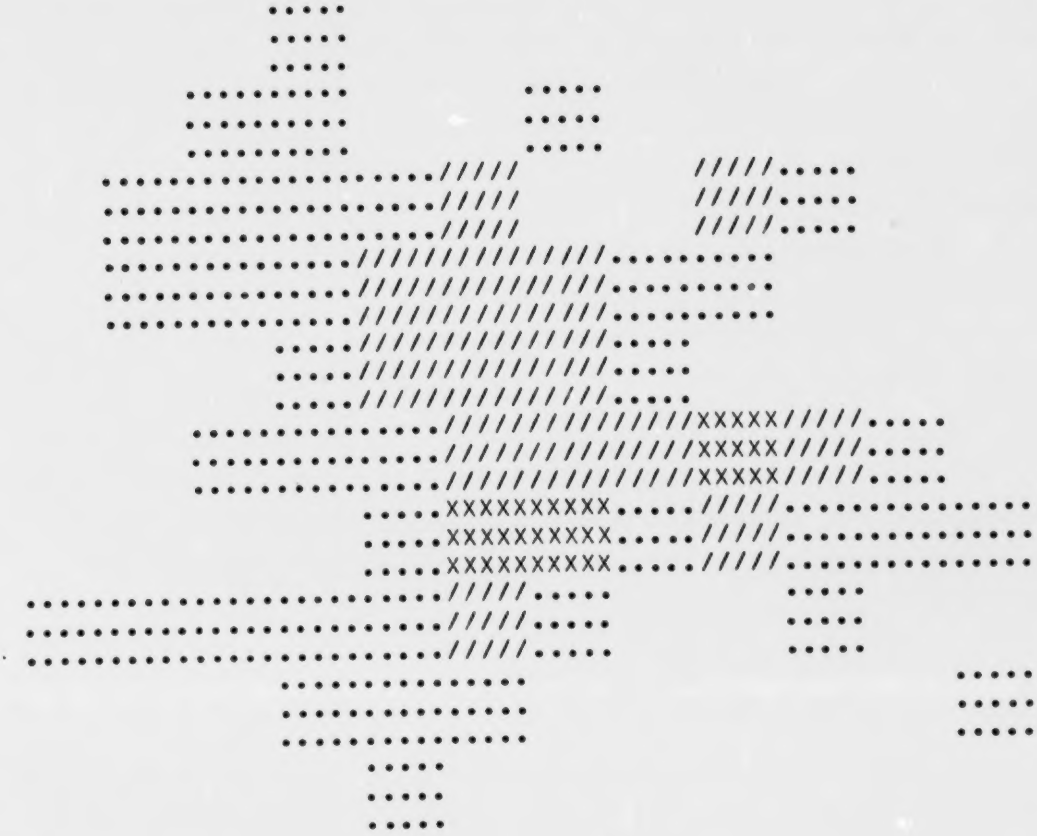

SULFUR OXIDE EMISSIONS
TONS/YEAR
0 - 100
..... 100 - 500
///// 500 - 1000
XXXXX 1000 - 3000

Figure 4-8a. Normal Sulfur Oxide Emissions for Month M


LAKEWOOD
GLEN CO.
SMITH CO.
JONES CO.
RIVERVIEW
LARGEBURGH
ROCK HILL
SPRINGVALE
102
77
4
3
12
14
7
X
Y
1 2 3 4 5 6 7 8 9 10 11 12


1 2 3 4 5 6 7 8 9 10 11 12
LAKEWOOD
GLEN CO.
77
102
12
SMITH CO.
JONES CO.
4
RIVERVIEW
102
LARGEBURGH
3
Y
ROCK HILL
12
14
SPRINGVALE
X



SULFUR OXIDE EMISSIONS
TONS/YEAR

	0 - 100
.....	100 - 500
/////	500 - 1000
XXXXX	1000 - 3000

Figure 4-8b. Sulfur Oxide Emissions for Month M Reduced for Stage 1 Alert

4.2.6 MAINTAINING A SOURCE INVENTORY PROGRAM

The control of pollution episodes must be based on current rather than long-term-average information. Episodes persist for only a few days. It is important to know what the pattern of emission is at the onset of a potential episode. Emissions from residential and commercial space heating units will depend on the ambient temperature at the time of the episode. The sulfur content of fuel being burned at the time is the real consideration and the average over the past six months is of little value. The opening of new industries, retirement of facilities, process changes and the addition of air pollution control equipment in the community will be changing gradually with time.

Annual up-dating of data should be an objective. The need for knowledge of emissions during high-episode-potential seasons should be reviewed annually. In large cities, retrieval of emission information in time to affect judgement during an episode-forecast period may be difficult, unless data are stored by computers.

4.3 LEGAL, FINANCIAL AND ADMINISTRATIVE CONSIDERATIONS

4.3.1 LEGAL CONSIDERATIONS

The legal and administrative problems associated with possible episode conditions are a specific responsibility of an air pollution control agency. The agency must determine from its legal counsel its own limit of authority if any of the suggested action plans are to be implemented. State and municipal authority varies widely between communities and cannot be reviewed in detail. The supporting legal body, i.e., Attorney General, City Counselor, etc., should assure the department that the proposed action plan is within the jurisdiction of the agency.

Voluntary or cooperative programs can be developed with surrounding jurisdictional agencies so that a program, once developed, can be implemented without delay.

4.3.1.1 Establishment of Emergency Control Legislation

If the legal justification does not exist for an Emergency Action Plan in the event of an alert, special legislation may have to be implemented.

In the case of a system covering a city, the following conditions may be covered in an Executive Order. (Ref. 4-23, 4-24, 4-25, 4-26)

The intent of the legislation is described, for example: to prevent or minimize air pollution disasters which could severely affect the health and welfare of many of the people within the community.

The area where emergency conditions exist is identified.

The enforcement authority is identified, for example: the Department of Health, the air pollution control officials, Police Department, etc.

The factual findings upon which the action is taken are presented.

The manner in which the specific orders are issued is identified along with their time period of action.

The manner in which sources under the direct control of the Mayor (or cognizant authority) including municipal incineration, power, heating, etc. are alerted to implementation of their programs is specified.

The manner in which preplanned programs shall be implemented in stages as determined by the degree of severity of the situation is specified.

The responsibility for development of an Emergency Control Action Plan prepared in advance, indicating the specific measures to be taken by those responsible for the major emission sources is established.

Means for terminating the emergency are established.

The responsibility for an evaluation of the preventive and abatement measures taken during an episode and its submission to the mayor (or other authority) following each implementation of the emergency control plan is specified.

4.3.1.2 State Legislation

Legislation may be prepared at the state level (Ref. 4-25, 4-26) in which the declaration of an air pollution emergency by the Commissioner of Public Health may be made with the approval of the Governor. Under such legislation it may be desirable to develop an emergency plan for proposing controls and restrictions on the use of fuels, manufacturing and incineration operations, and possibly motor vehicles as the health department may deem necessary to protect the public health during the emergency.

Authority should be given to the air pollution control department, with the approval of the Governor, to take the necessary actions to implement an emergency air pollution control plan.

The limits of authority and responsibility should be identified as indicated in Section 4.3.1.1.

An advisory council of designated representatives of municipal agencies as well as representatives from the segments of industry most likely to be affected may be created. This council may include representatives from the fuels industries, manufacturing associations, qualified medical personnel, and registered professional engineers knowledgeable in the field of air pollution control.

Legislation should clearly designate the emergency powers, including the right to fine or take court action in the event noncompliance is achieved.

4.3.1.3 Regional or Interstate Cooperation

A jurisdictional problem may occur where an episode condition extends beyond state boundaries. A comprehensive alert control program can be developed to apply on a regional basis. Such a program can be operated by mutual agreement between states in which the enforcement authority will continue to reside in the individual jurisdictions.

In the absence of a regional authority, parallel legislation may be passed in the adjoining states. This legislation should indicate that action to be taken in concert.

General agreements may also be made depending on cooperation rather than legal authority for cooperative action.

Interstate contacts should develop a single mode for action in the event of an episode. Similar action may apply in the development of air pollution control regions, as indicated under the Clean Air Act of 1967.

4.3.1.4 Civil Injunctive Proceedings

Enforcement procedures with many existing codes generally involve civil injunctive procedures. The air pollution department may present court cases using source test data and emissions information developed by the emitters. If necessary, subpoenas can be issued. A cease order may apply or an injunction levied against an offender. In the absence of sufficient time to present a case when episodic conditions occur or are imminent, it may not be feasible to use this route if absolute enforcement is deemed to be a necessity.

4.3.1.5 Criminal Proceedings

If separate legislation identifies an episodic condition as being dangerous to the welfare of the community and negligence is indicated, criminal procedures may be instigated. Legislation may be quite explicit to indicate that failure to act to a predetermined plan is a criminal offense. In such an event, imprisonment and fines may be levied against those offenders found to be guilty of such intransigence.

4.3.1.6 Acquisition of Data

Emission inventory data obtained for normal air pollution control action is the primary information source for the development of emergency plans. Separate legislation to obtain an emission inventory data suitable for an episode probably should not be required.

4.3.1.7 Legal Authority

The department may establish legal authority requiring that persons responsible for the operation of a source of air contamination prepare emergency stand-by plans. The plans must be consistent with good industrial practice for reducing emissions in the event that emergency conditions are occuring or are forecast to occur. The stand-by plans should be designed to reduce or eliminate emissions in accordance with specific objectives defined in legislation. The legal authority may include the authorization to enforce the specific control conditions identified. If the stand-by plans are not considered to be adequate, the department should have the right to approve or disapprove the proposed plans.

4.3.2 FINANCIAL CONSIDERATIONS

The department budget should include an estimated amount of money to handle the eposodic conditions over and above the normal operation of the department. Overtime pay, the use of special additional staff, and the cost of dissemination information and control practices should be estimated depending on the frequency of eposodic conditions as well as the number of personnel which may be required.

4.3.2.1 Maintenance Grants

Requests for maintenance grants and establishment of departments should include provisions for implementation of episode plans.

4.3.2.2 Evaluation

An evaluation should be made of each episode to serve as a guide for future improvement. Such an evaluation should be a special report that would include not only the actions taken but the impact of the episode on the receptors and the community health, and recommendations for further actions to be taken. The cost to the community by industry or source of emissions which are required to comply with the episode warning system should also be established (see Section 4.6.2 below). An estimate should be made of the cost to a community had it failed to act when emergency conditions were identified.

4.3.2.3 Coordination Cost

Special costs may be incurred in the coordination of actions among various agencies.

4.3.3 ADMINISTRATIVE CONSIDERATIONS

The difficulty in administrating a program where clearcut authority has not been established in the event of an episode cannot be overestimated.

4.3.3.1 Local Level

The implementation of an episode alert control must of necessity be carried out at a local level. It must have the benefit of the higher governmental agencies -- regional, state and federal -- in implementing the program. Cooperative committees on interstate air pollution may be created without disturbing existing organizational relationships.

The Administration will be done within the organizational framework of the "chronic" air pollution control agency, augmented as necessary for the additional manning of sampling stations, communications systems and enforcement patrols as may be required. Normally the air pollution control agency will have the following three elements, or their equivalents, to perform the indicated functions:

- Engineering Division
  Emission inventories
  Source investigation

Emission reduction plans
Air use plans
Compliance agreements
Plans review and permit system
Supervision of technical aspects of inspection programs
Planning agency relations

- Inspection or Enforcement Division

  Enforcement of regulations
  Smoke and odor patrol
  Hazardous vapor inspection
  Complaint inspection
  Self-initiated inspections
  Violation follow-up correction
  Court actions

- Technical Services Division

  Air quality monitoring
  Laboratory services
  Stack sampling
  Meteorological services
  Effects monitoring
  Data processing and record keeping

The sizes of the above elements will depend primarily on the size of the city or region. For very small areas, less than ten people will be needed; for major cities, the manning may run into the low hundreds. The personnel must include professional and technical specialists, the numbers and exact disciplines of which will depend upon local circumstances. In general, the following technical talents should be included:

(a) Chemical, civil and mechanical engineers,
(b) Chemists and laboratory technicians,
(c) Electronic and instrument technicians,
(d) Meteorologists,
(e) Computer programmers and specialists.

In addition, access to personnel in law enforcement, public information and training should be arranged.

4.3.3.2 Single Line of Responsibility

A single line of responsibility should be established for the implementation of an episode alert system. The responsible individuals in the cities and the states and in the interstate actions should be clearly identified. This can be doen on a voluntary basis, but the lines of communication must be established and plans prepared in advance indicating how information is to be disseminated.

4.3.3.3 Administrative Procedures

The administrative procedures of a coordinated program must be established not only among air pollution control agencies but within agencies of various departments within a municipality. A specific responsible individual or office in each department must be identified. For example, the air pollution department must know who the authoritative department head is in the sanitation department, for example, if municipal incineratiors are to be shut down.

4.3.3.4 Actions Extending Beyond Jurisdictional Boundaries

The following is a list of actions which can be taken in the event that a municipality experiences an episode which extends beyond its jurisdictional boundaries.

(a) A city department may appeal to the surrounding local communities to join in a voluntary cooperative action. The specific steps should be established in advance. The proper responsible authority to be contacted should be established which in the case of some municipalities may be the Police Chief, the Mayor or the County Commissioner.

(b) An appeal may be made to the Governor of the state having an affected region to declare a certain political jurisdiction as being under emergency conditions.

(c) The state may supersede the authority of the local jurisdictions. The state may act on a state-wide basis notifying industires, wire services, and the state police of a situation to implement their prepared emergency plans.

(d) The Governor may ask a principal municipality to provide the guidance and leadership in implementing a program in a region that may extend beyond the municipal boundaries.

4.3.3.5 Interstate Regional Agency

An interstate regional agency may be established with adequate authority to prepare uniform regulations and assure coordinated uniform enforcement during times of episodic conditions. Such action will require states to confer the adequate authority on such an interstate agency. As an approach solely for handling alerts, this does not appear justified.

4.4 MONITORING

4.4.1 METEOROLOGICAL CONSIDERATIONS

4.4.1.1 Data Requirements

During potential episodes, the control agency will require special meteorological data that provide a more detailed understanding of local atmospheric conditions than can be derived from routine Weather Bureau reports. Data from nearby Weather Bureau airport offices seldom represent conditions in the city, particularly at night. The control office should have a means for providing supplementary up-to-the-minute data from locations within its area of concern. This will require a plan for data acquisition and processing. The plan could be a simple, cooperative arrangement with privately equipped facilities such as schools, power plants, newspaper offices, and industrial establishments. However, for reliable data reporting and control, a permanent observational network operated by the local agency may be advisable.

The control office should have one staff member in charge of collecting supplementary data required during episodes. The data may be reported by direct observation, by telephone or teletype, or by telemetry from remote locations. Data must be interpreted by a professional meteorologist or by a staff member especially trained in air pollution meteorology.

Of primary importance are measurements of wind direction, speed, and gustiness, with at least some sensors 100 feet or more above ground. Surface temperature measurements are useful, but measurements of temperature difference with height, to indicate atmospheric stability, are more valuable.

The number of reporting sites required depends upon local topography including urban structures. Many practical considerations govern the plan of a reporting network; a grid spacing of 2.5 miles within city limits and 5 miles in adjacent suburbs is fine for research needs, and perhaps excessive for control needs. Reporting sites should include one or more installations atop flat-roofed, tall buildings and on hilltops. Temperature-difference readings should be available from at least one urban location, possibly using a television tower over 300 feet high.

Since wind flow is marked by rapid fluctuations which are of little individual importance in transporting air pollutants, wind data should be averaged over specified periods between 10 and 30 minutes. However, a wind record is important because:

(a) Trends may be observed;

(b) Atmospheric stability can be estimated from wind direction fluctuations.

If available wind measuring equipment provide only for visual readings from meters or flashing light indicators, a minimal record should consist of hourly wind data with remarks about observed gustiness.

At control offices where a higher level of meteorological sophistication is justified, or where research can effectively utilize data on additional atmospheric properties, the following measurements may be desirable:

(a) Humidity - important in atmospheric chemical reactions, in visibility effects, and in predictions of mixing depth.

(b) Barometric pressure - useful for wind predictions in mountainous terrain.

(c) Vertical wind components - useful in research on atmospheric turbulence and diffusion of pollutants.

(d) Solar and sky radiation - influences on photochemical reaction rates.

(e) Optical properties of the air - visibility or transmissivity effects.

In the near future the Weather Bureau will furnish additional detailed soundings of the lowest 5000 feet of the atmosphere for major urban pollution control agencies.

4.4.1.2 Instrumentation

Services provided by the Weather Bureau plus supplementary services supplied by or through the air pollution control agency may be entirely adequate for dealing with potential episodes. Many control offices that plan to use reporting stations of their own find that a simple installation is adequate for their needs. If a sophisticated system is planned, it will probably include automatic electronic equipment to provide for command control, telemetry, signal processing, and data storage and display.

The present section will treat only the minimum complement of equipment: the sensors and recorders needed for the most necessary data. All equipment should be operable with 115 volt house current, and should not be significantly affected by power fluctuations.

4.4.1.2.1 Wind Sensors. Wind measuring instruments have high priority. Since episode conditions are marked by light, variable winds, direction and speed sensors selected for these purposes should have operational thresholds no higher than 1.5 MPH. Direction errors should be less than 10°, and if modeling research is planned, less than 2°. Velocity errors should not exceed 0.5 MPH. Accuracy at high wind speeds is not essential, but instruments should be rugged enough to withstand gusts of at least 60 MPH. The rotating cup anemometer and wind vane set is most widely recommended for air pollution use. Acceptable sets with matched linear response and electrical output characteristics should now cost about $1,000 without recorders.

4.4.1.2.2 Exposure of Sensors. Sensors should be located at sites where their measurements are representative of the surrounding area. Where practicable, meteorological measurements should be made at the same location as air quality measurements. In this way electrical power, housing, and maintenance costs for both purposes can be combined, and correlations between pollutant concentrations and meteorological conditions can be established.

The distance from the wind sensors to any obstruction should be at least 10 times the height of the obstruction. In cities where open areas of this size may be hard to find it is often necessary to expose instruments on the tops of buildings. In such cases buildings should be selected which have flat, unobstructed roofs without parapets. There should be no taller buildings in the vicinity. Instruments should be mounted on a tower or mast high enough above the roof line that wind turbulence effects are minimized; consultation with specialists in selecting the most height is advisable.

4.4.1.2.3 Recorders. The most common method of recording sensor-generated electrical signals is by use of clock-driven strip charts. These charts clearly show meteorological trends, and serve for effective display of gustiness and wind speed. Under episode conditions, offices not equipped with automatic data processing systems will be slightly handicapped by the need to read measurements off chart traces, but this method of data abstraction is practical and useful. In very large urban areas, systems now provide for digital data output on teletype, for storage on magnetic or punched-paper tape, or for direct "real-time" input to a computer.

A good single-channel recorder now costs about $1,800, and installations of the simplest kind add several hundred dollars to the cost. A multi-channel recorder usually entails a saving in costs over an equivalent number of individual recorders, but it may be less advantageous because it is more difficult to calibrate and maintain, and less readable as many records criss-cross on the same sheet.

4.4.1.2.4 Data Averaging. For most air pollution applications, meteorological data are averaged over specified periods usually ranging from 10 to 60 minutes. Strip chart records are normally averaged by eye. Averaging may be facilitated by the use of electrical filters which smooth out higher frequency signal fluctuations. This device is desirable for wind speed and temperature, but not for wind direction where the record of fluctuations is used as a measure of atmospheric stability. In a nonautomated system, a single temperature measurement at the end of every wind-averaging period is adequate.

The Aerovane combines wind direction and speed sensors in an aerodynamic body resembling an airplane without wings. It is noted for ruggedness and reliability over years of service. Its sluggish response characteristics are advantageous for air pollution applications since rapid wind fluctuations are damped out. However, its starting speed of between 2 and 3 MPH hampers its total usefulness. Furthermore, if wind direction data are desired in digital (discrete number) form, conversion of the aerovane's electromechanical synchro output requires intermediate equipment which can introduce additional sources of error.

4.4.1.2.5 Temperature Sensors. The most practical sensor is one that provides an electrical output, so that remote measurements can be recorded directly or telemetered to the control office. Such temperature sensors require an external electrical power source and aspirated shielding, which now costs about $150. A recommended sensor of this type is the resistance bulb. This device is a cylindrical metal housing about the size of a cigarette within which is fastened a mica core with windings of copper, nickel or platinum wire. The electrical resistance of the wire varies directly with temperature over the normal range encountered.

For individual temperature readings where errors within 0.5°F are acceptable, resistance bulbs are now available for as low as $20. However, where vertical temperature-difference measurements are desired, errors should be well under 0.1°F, since a decrease of 0.5°F through 100 feet of rise in the atmosphere is the critical value for atmospheric instability. Matched, precision-made sensors for this purpose now may cost about $200 each. Temperature-difference can be measured directly from the differential output of two sensors rather than from two separate readings, simplifying data reduction.

4.4.1.3 Air Pollution Potential Forecasting

Appendix H presents the standard operation procedure now in use in the Weather Bureau. Variations on this technique are discussed below which may have value in devising an episode avoidance procedure.

4.4.1.3.1 Meteorological Conditions for Episode Development. The high pollutant levels that mark the occurrence of air pollution episodes result from the accumulation of emissions over urban areas for some time. Day to day variations in total emissions do not ordinarily account for the observed rise in ambient concentrations. The principal factor is the meteorological condition. Normally, pollutants are well distributed through the atmosphere by the actions of outward-moving winds and upward-moving air currents. However, from time to time certain features in the atmopshere (inversions) appear to "clamp a lid" over broad areas, limiting vertical transport, and slackening winds restrict the horizontal transport of pollutants. When these natural conditions occur in regions with substantial numbers of air pollution sources and sensitive receptors, and stagnate for an unusually long period of time, episode potential is high.

When the city air "feels stale," when persistent layers of smoke and haze lie low over the landscape and when winds hardly create a stir for several days on end, chances are that the region lies under the dome of a stagnant high pressure area which covers a major portion of the country. These conditions are defined objectively in Appendix F. This phenomenon usually results from a world-wide slowdown in the normal west-to-east process of the major high and low pressure systems. It may occur several times a year, and situations conducive to high air pollution are not infrequent over the United States as a whole.

4.4.1.3.2 Concept of Mixing Depth. Of the two atmospheric properties that limit pollutant transport, wind speed and mixing depth, the latter is relatively unfamiliar to non-meteorologists and may need explanation. Physically, mixing depth is the vertical extent of turbulent motion within the layer or air next to the ground. The turbulence may be generated by solar heating of the ground, from the passage of wind across rough surfaces below, or from a combination of both. When the wind is fresh and gusty, or when tall cumulus clouds indicate vigorous upward currents from solar heating, the mixing layer is deep and pollutants are well diluted. When the air is still, the ground relatively cold, fog and smoke banks low-lying, and the barometer higher than average, the mixing layer is shallow and pollutant concentrations could be high. With normal daytime heating, mixing layers that are shallow in the morning deepen considerably by afternoon. At night, as the ground cools the mixing depth again decreases.

4.4.1.3.3 Lapse Rate and Stability. An analytical discussion of mixing depth requires some explanation of lapse rate and stability. Lapse rate is the rate at which atmospheric temperature is observed to decrease with elevation. It is the vertical temperature profile, which can be measured by ballon-borne radiosonde and by other methods. On the average, temperature decreases about 3.5°F with every 1000 feet of rise, up to the base of the stratosphere some six miles high. The decrease is seldom steady, even in the free atmosphere well above the ground. Through some layers the temperature drop-off may be faster or slower than through other layers. Sometimes one observes that temperature holds steady through the layer; the layer is then said to be isothermal. Sometimes the temperature rises with ascent; the layer is then called an inversion layer.

If a parcel of air is carried upward by thermal or wind turbulence, it expands and cools at the rate of 5.4°F per 1000 feet, provided no moisture condenses out. This rate of cooling is called the dry adiabatic lapse rate. Ascending air must be replaced by descending air, and a vertical circulation may develop. Descending or subsiding air rises in temperature at the adiabatic rate. Thus, an atmospheric layer characterized by a dry adiabatic lapse rate is or has been a region of significant vertical motion.

In a layer where the lapse rate exceeds the dry adiabatic (superadiabatic), vigorous vertical motion can begin "spontaneously." Such a layer is said to be unstable, since the vertical motion is self-perpetuating.

Layers where the lapse rate is less than the dry adiabatic are said to be stable, since vertical motions are limited. The normal lapse rate of 3.5°F per 1000 feet describes a stable condition; and isothermal condition is more stable, and an inversion condition is the most stable of all. An inversion layer tends to suppress vertical motion from below. When a mixing depth is shallow, it is often so because a strong inversion caps the surface layers of air.

Figure 4-9 shows how an inversion may define the top of a mixing layer. In the morning the mixing layer hugs the ground at the base of the nocturnal inversion. As daytime heating erodes the inversion, the mixing layer rises to 1.4 kilometers, about 4600 feet. Note that the daytime lapse rate is identical with the dry adiabatic lapse rate projected upward from the maximum afternoon temperature at the ground.

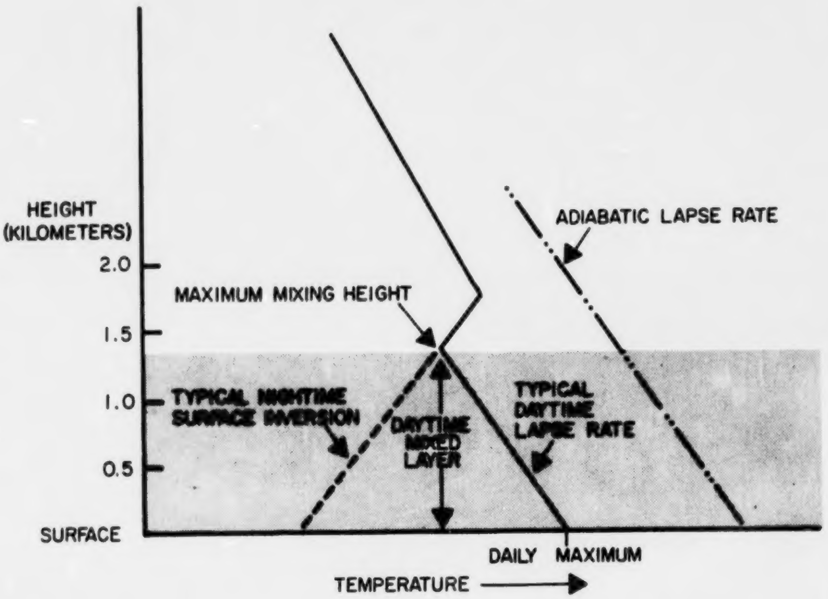

HEIGHT
(KILOMETERS)
2.0
1.5
1.0
0.5
SURFACE
ADIABATIC LAPSE RATE
MAXIMUM MIXING HEIGHT
TYPICAL NIGHTTIME SURFACE INVERSION
DAYTIME MIXED LAYER
TYPICAL DAYTIME LAPSE RATE
DAILY MAXIMUM
TEMPERATURE →

Figure 4-9. Schematic Representation of the Effect of Vertical Temperature Gradient on Atmospheric Mixing

4.4.1.3.4 The National Air Pollution Potential Forecast (APPF) Program. Before techniques for predicting air pollution potential could be developed, it was necessary to identify the meteorological conditions associated with air pollution episodes such as occurred in Donora (Reference 4-27) and London (Reference 4-28). After these and later events were evaluated in terms of mixing depth, wind direction and speed, stability, lapse rates, and general weather map features, the first attempts at prediction on a limited scale (References 4-29 and 4-30) were successful. By August, 1960, the National Center for Air Pollution Control at Cincinnati had initiated an APPF service for the Eastern United States. By 1963 the forecast service was extended to the entire country. In July, 1967, routine operation of the forecast service was transferred to the Weather Bureau National Meteorological Center (NMC) at Suitland, Maryland. The Cincinnati NAPEA office retains research and development responsibilities.

An air pollution potential message is now issued by the NMC every day at 12:20 P.M., E.S.T., over Weather Bureau Service C teletype network. The message has two parts: a plain language narrative and a coded message. The narrative identifies areas for which an air pollution potential condition is forecast. If no air pollution potential areas are likely, the statement is "None Today." The narrative may include information added at the forecaster's discretion, such as a developing APPF situation which does not yet meet the rigid criteria for issuance of an advisory.

The coded message provides information on current and predicted mixing depths and average wind speed in the mixing depths for all reporting Weather Bureau radiosonde stations in the U. S. Computations are based upon data for 7:00 A.M., E.S.T., which is the time of synoptic upper air soundings everywhere in the world. Since a vast quantity and variety of data must be processed to produce the coded message, the entire procedure is computerized including the punched paper tape for disseminating the message on teletype circuits. Figure 4-10 shows the details of the procedure.

The NMC forecaster uses the machine-calculated data as a guide in determining whether an air pollution potential advisory is warranted. His decision rests largely upon whether all of the following criteria are met:

(a) The affected area must be no smaller than an area approximately equivalent to a 4° latitude-longitude square (about the size of Oklahoma).

(b) No significant precipitation or frontal passages must be observed or expected for the next 36 hours or so.

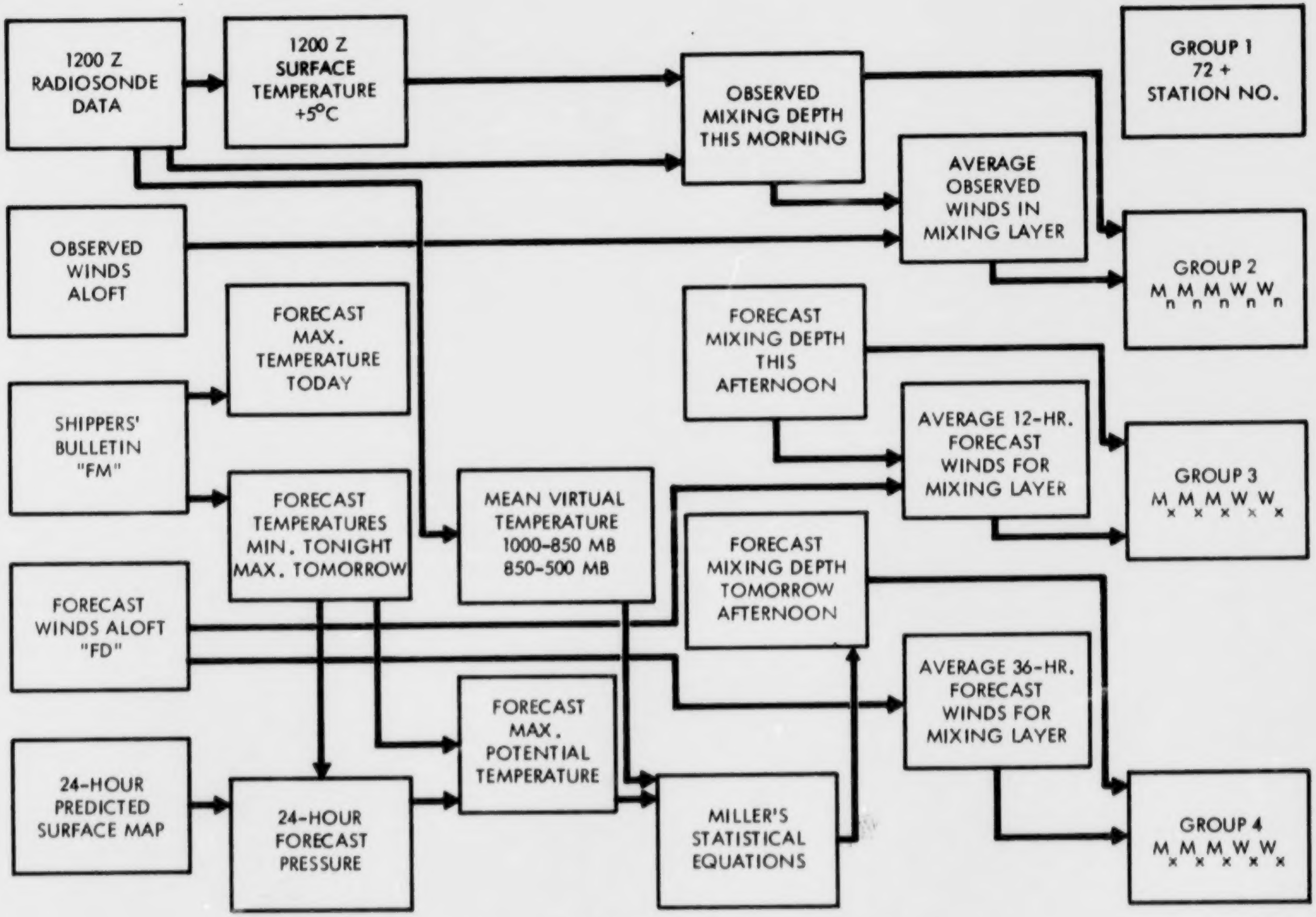

1200 Z RADIOSONDE DATA
1200 Z SURFACE TEMPERATURE +5°C
OBSERVED MIXING DEPTH THIS MORNING
GROUP 1 72 + STATION NO.
AVERAGE OBSERVED WINDS IN MIXING LAYER
OBSERVED WINDS ALOFT
GROUP 2 $M_n M_n M_n W_n W_n$
FORECAST MAX. TEMPERATURE TODAY
FORECAST MIXING DEPTH THIS AFTERNOON
SHIPPERS' BULLETIN "FM"
AVERAGE 12-HR. FORECAST WINDS FOR MIXING LAYER
FORECAST TEMPERATURES MIN. TONIGHT MAX. TOMORROW
MEAN VIRTUAL TEMPERATURE 1000-850 MB 850-500 MB
GROUP 3 $M_x M_x M_x W_x W_x$
FORECAST MIXING DEPTH TOMORROW AFTERNOON
FORECAST WINDS ALOFT "FD"
AVERAGE 36-HR. FORECAST WINDS FOR MIXING LAYER
FORECAST MAX. POTENTIAL TEMPERATURE
24-HOUR PREDICTED SURFACE MAP
24-HOUR FORECAST PRESSURE
MILLER'S STATISTICAL EQUATIONS
GROUP 4 $M_x M_x M_x W_x W_x$

Figure 4-10. Details of Computerized NMC Procedure

(c) The surface winds at stations in the area must not average more than 5 knots and/or no more than 3 individual hourly wind speeds are to exceed 8 knots during a 24-hour period.

(d) The morning urban mixing depth must be $\leq$ 500 meters (about 1600 ft.) and the observed wind speed averaged through this depth must be $\leq$ 4 meters/sec. (About 9 MPH.)

(e) The numerical product of the afternoon mixing depth and the forecast average wind speed through this depth must be $\leq$ 6000 m^2/sec and the forecast average wind itself must not exceed 4 m/sec.

(f) The 30-hour forecast of tomorrow afternoon's mixing depth and average wind speed (Reference 4-31) must meet the same criteria as in (b) above.

These criteria may appear to be overly stringent. Situations in which all criteria are satisfied should occur infrequently, and many local air pollution events would not be covered by APPF advisories. This is not unplanned. Quoting from Stackpole (Reference 4-32):

> "This conservatism on the part of the APP forecaster is by design. In simple terms, he does not wish to be accused of crying Wolf! The social and economic consequences of a substantial air pollution episode (Reference 4-33) are sufficiently great such that the APP forecaster would rather miss a few marginal cases than attempt to forecast all possibilities and cry APP when none came to pass. He would soon be ignored, to the eventual detriment of the ignorers. Rather he would prefer that his forecasts came to be trusted so that preventative measures, reducint smoke production, changing fuel types, generally restricting pollutant production, could be undertaken to avoid the possible disasterous consequences of a failure to act.
>
> At present, nothing seemingly can be done about changing the Potential; however, adequate warning coupled with firm measures can go a long way toward eliminating the Air Pollution in an air pollution potential episode."

4.4.1.3.5 Local Air Pollution Potential Forecasting. A meteorological condition that prevails over a large geographical area may be considerably modified in particular localities within the area. Just as it is possible for an air pollution potential to occur in a city but not generally throughout the state or region, it is also possible for a city to escape the effects of a general air pollution potential situation. Local topography features, vegetation, bodies of water, and other factors tend to produce widespread variations from place to place even within an urban area itself. For a better understanding of how these features affect the possibilities for episode occurrence, the local control official should have professional meteorological advice.

From the Weather Bureau he may obtain services that are adequate for his needs. Certain Weather Bureau information sources could be better exploited. For example, local forecast studies on file at every aviation weather forecast center discuss sources and conditions of visibility restriction including the effects of which smoke and haze. The control agency may establish a cooperative relation with the local Weather Bureau office which will provide useful information and form a basis for coordinated activity in advising the general public.

In most cases the special meteorological requirements of the control agency go far beyond those normally met by local Weather Bureau. A private consultant may be engaged for this purpose, or meteorologists may be a part of the permanent staff. A number of offices receive current weather information directly from the National Meteorological Center on rented teletype and/or facsimile drops.

The Weather Bureau has begun a program aimed at providing more intensive meteorological support to local communities on matters such as air pollution. Responsibilities for direct support to air pollution interests in designated cities is centered in an Urban Air Pollution Specialist. When an APPF advisory is issued by the NMC, the Urban Specialist determines whether and to what extent his area of responsibility is involved. If the advisory does not affect his area, he takes no further action. If the advisory includes his area, he will adapt the message to local conditions, considering peculiarities of climate, topography, existing pollution conditions, etc. He will issue a local advisory and disseminate it to interested parties selected interests, including the local control office. It is not intended that he engage in control activity per se, but only that he provide direct meteorological support under the APPF program. Figures 4-11 and 4-12 show the position and activities of the Urban Specialist.

In the event that a control official urgently requires meteorological advice in localities where no Weather Bureau office is located, or where existing facilities appear inadequate, he can seek assistance from the nearest forecast offices. Approximately 275 offices across the nation cooperate in offering this support. These offices operate in three echelons of area responsibility:

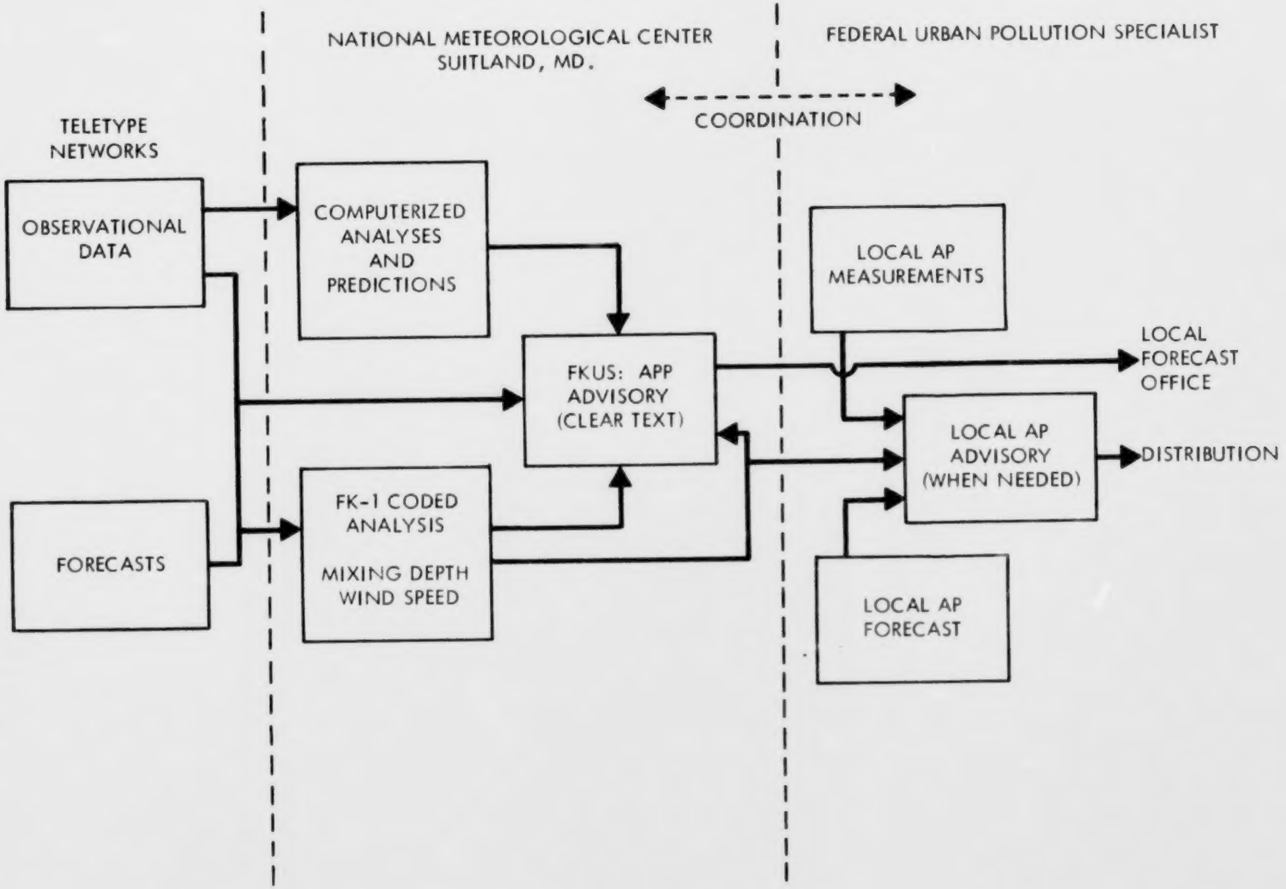

NATIONAL METEOROLOGICAL CENTER
SUITLAND, MD.
FEDERAL URBAN POLLUTION SPECIALIST
COORDINATION
TELETYPE NETWORKS
OBSERVATIONAL DATA
FORECASTS
COMPUTERIZED ANALYSES AND PREDICTIONS
FK-1 CODED ANALYSIS
MIXING DEPTH WIND SPEED
FKUS: APP ADVISORY (CLEAR TEXT)
LOCAL AP MEASUREMENTS
LOCAL AP ADVISORY (WHEN NEEDED)
LOCAL AP FORECAST
LOCAL FORECAST OFFICE
DISTRIBUTION

Figure 4-11. Air Pollution Potential (APP) Advisory Procedure - General Plan

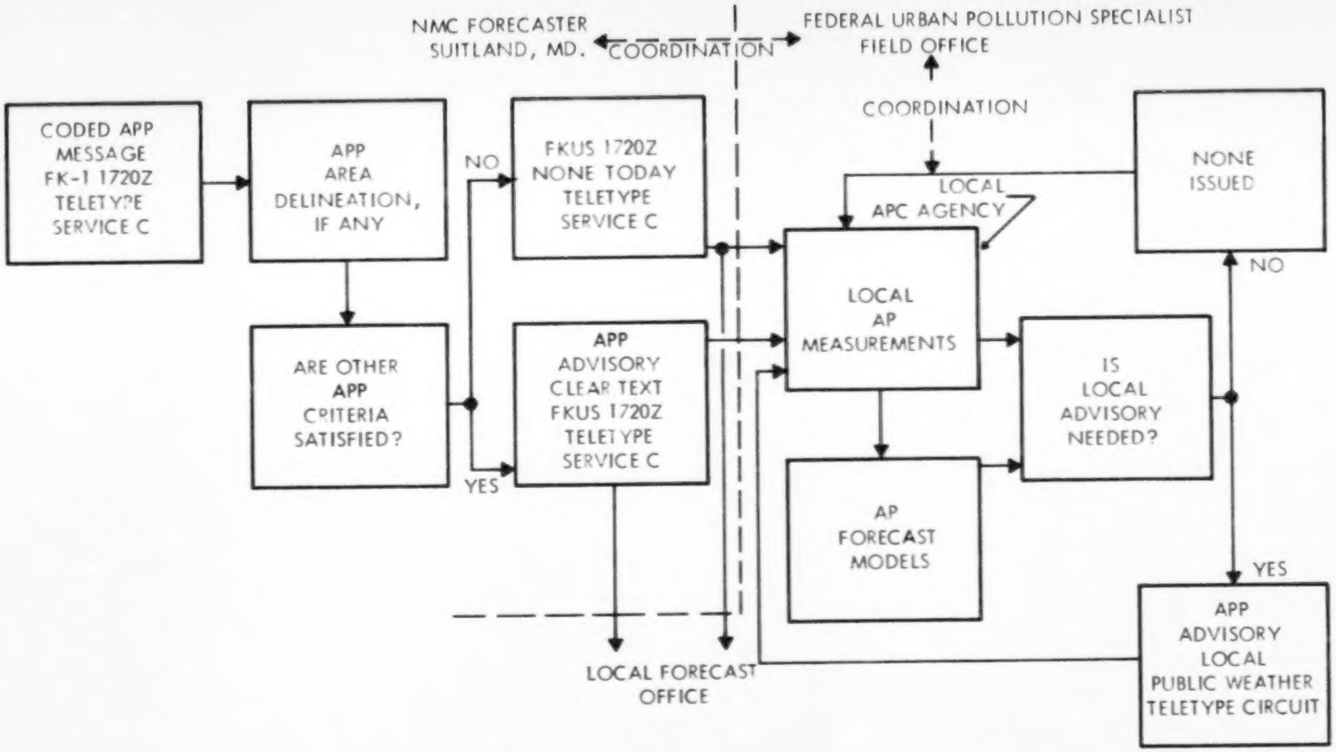

NMC FORECASTER
SUITLAND, MD.
COORDINATION
FEDERAL URBAN POLLUTION SPECIALIST
FIELD OFFICE
COORDINATION
CODED APP MESSAGE FK-1 1720Z TELETYPE SERVICE C
APP AREA DELINEATION, IF ANY
ARE OTHER APP CRITERIA SATISFIED?
NO
YES
FKUS 1720Z NONE TODAY TELETYPE SERVICE C
APP ADVISORY CLEAR TEXT FKUS 1720Z TELETYPE SERVICE C
LOCAL FORECAST OFFICE
LOCAL APC AGENCY
LOCAL AP MEASUREMENTS
AP FORECAST MODELS
IS LOCAL ADVISORY NEEDED?
NONE ISSUED
NO
YES
APP ADVISORY LOCAL PUBLIC WEATHER TELETYPE CIRCUIT

Figure 4-12. Air Pollution Potential (APP) Advisory Procedure Details

(a) Area Forecast Centers: about 25 offices prepare forecasts for areas comprising several states or portions thereof.

(b) Zone Forecast Offices: about 60 offices are responsible for more detailed forecasts covering portions of states (zones) that possess a great deal of meteorological homogeneity.

(c) Local Forecast Offices: about 235 offices prepare or adapt forecasts to meet local requirements, in many cases including localities other than their own.

Hence, regardless of whether a Weather Bureau Office is located in the particular community, the local control official has access to the full measure of specialized knowledge and experience of the entire meteorological service. He is advised to establish a cooperative relation with the nearest local or zone forecast office and to structure an episode plan of action to include a reliable inter-communication procedure. Every forecast office is linked to the National Meteorological Center by teletypwriter, so that it routinely receives all mixing-depth, wind speed and air pollution potential advisory transmissions. In an emergency, the forecast office can communicate directly with air pollution specialists at the National Meteorological Center or at the Air Resources Program Research Office in Cincinnati.

4.4.2 AIR SAMPLING

4.4.2.1 Averaging Times and Site Selection

4.4.2.1.1 Averaging Times. The objective in air sampling is to describe receptor exposure to pollutants. For episode avoidance, the descriptions required are different from those needed for chronic air pollution control. For the latter, the needs are estimates of long-term statistics such as averages, ranges, and deviations for averaging times ranging from a year to 5 minutes. Such estimates can be obtained by random, continuous, or intermittent regular sampling.

For episode avoidance, it is necessary to have at least some continuous air sampling, because we are dealing with an event that lasts only a few days, and because the control actions are "real-time" in character. Averaging times of one to four hours are adequate; automated systems may use averaging times as short as five minutes. Random sampling for these purposes may be impractical; it is probably no more expensive to collect 5-minute samples continuously for a week (if data are processed by computer) than to collect 5-minute samples spaced randomly for a week.

Judging from alert criteria now in use (See Section 3.5), one-hour averaging times are adequate for surveillance of episodic or potentially episodic conditions. Shorter averaging times provide more information (better statistical estimates), but increase the need for automation because of the bulk of data. Averaging times longer than six-hours entail some delay in response. Information is needed fairly quickly; after an alert is announced, the agency can expect many calls from news reporters, individuals, and officials requesting reports on the status of the event.

4.4.2.1.2 Site Selection. A single station may be sufficient to adequately describe conditions in a given area, but unless this fact has been established with some certainty, some larger number of stations is desirable.

Designing a sampling network presents a difficult problem, because the measure of effectiveness is elusive. Confining the problem to episode avoidance (rather than chronic) air pollution control objectives, the measure of effectiveness is the success in avoiding public health "disasters," given adequate emission curtailment methods. If concentrations are uniform in the area, a single station is obviously sufficient. Although there is some evidence (Reference 4-34) that during episodes concentrations are more uniform within a given area (Philadelphia) than during non-episode conditions, the extent to which this is true in all areas obviously depends on many factors.

Selection of the actual number of sampling sites remains a practical problem. Clarenburg (Reference 4-35) and Stalker, et al (Reference 4-36), have studied the problem, relating variance estimates to required accuracy. Tools are available for designing a network on a cost-effective basis using optimizing techniques, but have not yet been applied to this problem. One practical difficulty will be in assigning an effectiveness-measure that appreciates the objectives.

Presently, from 3 to 14 sampling stations are in use in large urban areas (excluding "static" samplers such as "dust jars" and lead dioxide "candles"). Because of the high cost, network size will probably continue to depend largely on local budgets.

Episodal conditions require control to protect human welfare, and monitoring sites should be located where this welfare is most threatened.

These sites might be:

(a) High Population-Density Areas,
(b) Near Large Stationary Pollutant Sources,
(c) Hospitals,
(d) High Density Traffic Interchanges,
(e) Homes for Aged.

A network of sites is useful in determining the range of pollutant concentrations within an area. Measured pollutant concentrations from separate sites can be weighted according to their duration and the number of people in the neighborhood of the particular site who will be affected. The most desirable monitoring sites are not necessarily the most convenient. First consideration should be given to the use of public buildings: schools, fire houses, police stations, hospitals, water or sewage plants, etc. It is entirely possible that local industrial or commercial installations would be willing to either exchange data or permit sampling equipment to be installed on their site where it could also be used as an aid in their own pollution control programs.

4.4.2.2 Air Sampling Methodology

For episode avoidance purposes, one fact emerges clearly when air monitoring requirements are examined: data are needed quickly -- in no less than a few hours after the sensor is contacted by the pollutant. While this is possible to achieve by manual methods, using telephone reporting, there is a definite trend toward automated monitoring networks. For this reason only a cursory review of air sampling is presented. Method descriptions are available from many sources, and this discussion emphasizes special considerations for "episode" monitoring. Information on data acquisition and analysis are judged valuable and are discussed in the next section.

The measure of air contaminants is a rapidly evolving field; any chemical or physical detection method capable of extreme sensitivity is a candidate for these applications.

For decision making during an episode, data presentation methods should be evolved which ideally will present at a glance the concentrations of each monitored contaminant in terms of peak reading, current one-hour average, previous six-hour average, and previous 24-hour average.

The collection and analysis must be accomplished rapidly if the data are to be useful immediately. There is no time to check out the methods, run blanks, calibrate, etc., after the onset of episode conditions. In general, either personnel must be stationed at the sites during the episode or automated equipment must be operated with automatic data transmission to a central location.

Air samples must be conducted to measuring equipment in a manner that will least interfere with the composition of the sample. This can be accomplished by drawing air through an inert plastic tubing by operating a vacuum pump. After prolonged periods of air sampling it is not uncommon to have collected amounts of dirt, insects, pollen, etc. in long lines, so care in permanent installations is exercised in their design and maintenance. The entry of rain water or other foreign objects must be prevented. The acquired air sample is then passed through an analytical procedure where the contaminant of interest is measured quantitatively. There are two general procedures utilized in air quality analysis: (1) chemical methods and (2) physical methods, such as ultraviolet or infrared absorption.

Chemical analysis always involves the use of consumable supplies. The chemicals must be replaced on a schedule that depends on the rate at which samples are taken. Typical current instruments store adequate chemicals for operation for periods of from three days to one month. In some cases, analytical reagents for specific air contaminants are toxic or corrosive, and should have protective storage.

Physical methods of measurement are performed by relatively complex equipment. These instruments must be installed correctly and cared for by trained personnel. Their accuracy is affected by mechanical shock, ambient temperature extremes, supply voltage stability, dirty or dusty atmospheres, and corrosive chemicals.

A recent trend in air quality monitoring is to establish a mobile laboratory, built similarly to a house trailer. The trailer can be moved, and operated at different fixed sites. In initial program development, the mobile trailer offers considerable flexibility in site location. It can be shifted according to seasonal prevailing winds or be assigned to investigate specific problem areas.

All of the analytical equipment used for air quality monitoring requires servicing. When this equipment is used continuously it is necessary to have personnel visit the instruments at least once a week. A more frequent schedule is desirable. In a monitoring program of ten instruments on-line continually, one man full-time will be required to keep the instruments functioning properly. The equipment and supplies consumed on an annual basis in servicing and maintenance will be approximately ten percent of the cost of the instrumentation.

The accuracy of all analyses must be established periodically to verify analytical results. Automated instruments have a long term accuracy of feild measurements of about plus or minus five percent. Calibration is performed by replacing the ambient air sample input with a sample of known concentration. Without calibration, measurements at different sites and at different times may not be comparable.

An important factor in air monitoring accuracy is the effect of substances which interfere with a chemical procedure being used to detect a pollutant. Typical urban air contains a large number of different chemicals and their effect on detection methods used must be considered. Typical interferences that have been identified are:

(a) Ozone, nitrogen, dioxide and heavy metal particulates affect the accuracy of sulfur dioxide detection using the West-Gaeke method.

(b) Ammonia and nitrous oxide interfere with the detection of sulfur dioxide using the conductivity method of detection.

(c) Sulfur dioxide, hydrogen sulfide, and reducing gases interfere with the detection of oxidants using the neutral buffered-potassium iodide method.

The interferences present will vary from city to city and their effects must be evaluated by actual measurements. Experienced personnel are required for reliable analysis of these effects. The National Center for Air Pollution Control, and others, offer training courses each year to train personnel in the proper use of chemical techniques and instruments.

Measurements result in a numerical value of concentration of a pollutant. For continuous analyzers there is a continuous output of data. The measured values are read from meters or recorded on strip chart recorders. Each analyzer may have its own recorder, or several may be combined to record on one chart with a multi-pen or multi-point recorder. In large collections of analyzers, the trend is toward scanning instrument readings periodically and recording readings on teleprinters, punched tape or magnetic tape. The printer provides the immediate readout, while the tapes allow the utilization of automatic data reduction facilities. The selection of the appropriate readout is made depending upon the use to be made of the data. Consolidation of data should be carefully considered in order to reduce storage, permit suitable identification and permit easy reduction and analysis.

The expected range of pollutant concentrations should be considered in selecting methods and instruments. In some cases, networks have been designed around instruments that apparently sensed nothing above "zero" because the range was 1-10 ppm SO_{2_1} and 1 ppm was never reached.

Care should be exercised in comparing data from different instruments. Each instrument exhibits a different "time-constant" in detection. Some detectors are nearly instantaneous, others will require considerable time to complete an analysis. Some chemical techniques exhibit a delay of five to twenty minutes so that their output signals do not represent the relationship between the concentrations of contaminants at the same time. The rise in the concentration of one pollutant may be accompanied by the rise in the concentration of another one-half hour later according to the chart records whereas, in reality, the increase may have been simultaneous.

Instrumentation is relatively expensive, so it should not be underutilized. Neither should a monitoring program be handicapped by inferior or too little instrumentation to perform adequately. Personnel requirements for servicing and operating instrumentation should be given careful consideration in the total program.

4.4.2.3 Remote Sensing

Remote sensing differs from direct sensing in that the sensor is not located within the portion of the atmosphere it is measuring. Usually the sensor is located on the ground and measures the atmosphere above it or between the sensor and a light source located at a distant high point. Some sensors that are not truly remote, such as a sounding balloon, are included here because they are ready for field use while most truly remote sensors still are in the developmental stage.

Remote sensing is desirable for three dimensional modeling of the atmosphere. Conventional direct sensors can measure only the first few hundred feet of the atmosphere, unless aircraft-mounted; measurements throughout the entire mixing layer are important for in-depth understanding of dispersion phenomena.

Table 4-5 lists remote sensing instrumentation, and the notes following contain supporting information.

Appendix G contains information on the state of the art in remote sensing.

4.4.3 MONITORING HEALTH EFFECTS

Seldom are enough health and exposure data available to assess the impact of air pollutants. Study methods that relate health data and episodal exposures require proper budgeting and careful work; exposures can be judged by air sampling and "dose modeling," but seldom have been - and it is difficult to account for all non-pollution-induced disabilities. The air pollution control agency will not have the primary function of obtaining and studying health data, but may wish to encourage studies, by universities, clinics, hospitals, or public health agencies. In support of health studies, exposure conditions will be quite important, and these data may be provided by the control agency. This section presents information which should be helpful in planning such cooperative studies, and is concerned with these four points:

(a) What data should be collected?
(b) Where can data be obtained?
(c) How can data be obtained?
(d) How may the data be studied after collection?

4.4.3.1 Data to be Collected

Evidence from many field and laboratory studies indicates that the occurrence and severity of certain illnesses are closely associated with air pollution. (References 4-37, 4-38, 4-39, 4-40, 4-41, 4-42, 4-43, 4-44, 4-45, 4-46, 4-47, 4-48 and 4-49.) These illnesses fall into two categories:

(a) Diseases of the respiratory system, which include chronic bronchitis, chronic constructive ventilatory disease, pulmonary emphysema, bronchial asthma, pneumonia, lung cancer, and acute nonspecific upper respiratory diseases such as common cold.

TABLE 4-5

	SENSOR	METHOD	SENSOR LOCATION
Wind	1. Radiometer	crossed beam	ground
	2. Pilot Balloon	balloon tracking	ground
	3. Rawinsonde	balloon tracking	ground
	4. Laser Radar	Doppler shift	ground
Temperature	1. Radiometer	microcome absorption	ground
	2. Radiometer	infrared absorption	airplane
	3. Wiresonde	bead thermistor	balloon
	4. Radiosonde	bead thermistor	balloon
	Rocketsonde	Doppler Broadening	ground
	5. Laser/Spectrometer	Doppler Broadening	ground
Pressure	1. Radiosonde	Aneroid barometer	balloon
	2. Rocketsonde	pressure switch	parachute
	3. Radiometer	microcome absorption	ground
Water Vapor	1. Radiosonde	hygrometer	balloon
	2. Wiresonde	wet bulb	balloon
	3. Laser/Spectrometer	infrared absorption	ground
Gaseous Pollutants	Correlation Spectrometer	Differential absorption	airplane
	Absorption Spectrometer	Differential absorption	ground
Aerosol Pollutants	Laser Radar	Mie scattering	ground

NOTES ON TABLE 4-5

WIND

Method 1. An accuracy of 10% has been achieved in a test that measured the flow of rocket exhaust; Northrop Corporation soon will start tests in free atmosphere; field use not expected before 1971.

Method 2. A conventional Weather Bureau method that is simple and reliable; requires moderate skill; not useable at night or in heavy haze.

Method 3. A conventional Weather Bureau method that is reliable; probably practicable only for major Weather Bureau stations due to cost of radar and processing equipment.

Method 4. Very promising technique that still is in the laboratory development stage.

TEMPERATURE

Method 1. Field tests have been completed and the instrument is now ready for field use according to Sperry-Rand; accuracy is comparable to radiosonde technique, e.g., 0.7°C; no reliability experience yet.

Method 2. Based on temperature radiometer that currently is in field use for long path and spot measurements; clear air turbulence sensing version now in flight test can be modified to obtain altitude profiles of temperature; accuracy specified is for the long path radiometer.

Method 3. A very accurate sensor for use on tethered balloon where rise rate is controlled by the tether; tether and balloon might be a hazard to aircraft.

Method 4. In daily use of the Weather Bureau; thermistor is one of three sensors contained in the radiosonde. Probably practicable only for Weather Bureau stations due to cost of radar and processing equipment; also used in cold gas rocketsonde called cricket; rocketsonde cost requires reuse of unit at least 10 times.

Method 5. Currently a promising laboratory technique; requires precise control of laser transmitter and of received signal.

Method 6. Ground use of this method requires extensive network of microphones; probably not practicable.

PRESSURE

Method 1. Same as Temperature Method 4.

Method 2. Calculated from temperature once pressure switch data.

Method 3. A proposed add-on function to Temperature; is still in development.

WATER VAPOR

Method 1. Same as Temperature Method 4.

Method 2. Same as Temperature Method 3.

Method 3. Same as Wind Method 4.

GASEOUS POLLUTANTS

Barringer Research Ltd., of Canada currently is operating correlation spectrometers from aircraft for detecting SO_2 and NO_2; a similar device has been developed for ground use at University of Florida - a very promising method; an absorption spectrometer is also under development.

A great deal of field research has been done by Stanford Research Institute on determining the altitude of aerosol concentrations. Much laboratory research is underway on identifying type, but field equipment is not available.

(b) Cardiovascular diseases, which are those involving the heart and circulatory system, such as coronary thrombosis, arteriosclerosis, stroke, endocarditis, and other myocardial degeneration.

A third manifestation, acute eye irritation, has been observed also. (References 4-38, 4-45 and 4-46.)

Two types of incidence information about these diseases are of value in estimating the severity of an episode:

(a) Morbidity incidence; that is, the number of persons becoming ill from cardiovascular or respiratory involvement.

(b) Mortality incidence; that is, the number of persons dying from one or more of these causes.

As a rule, morbidity data afford a more satisfactory measure of health effect, because the incidence of illness is almost invariably higher than that of death, giving the investigator a larger sample with which to work. Unfortunately, reliable morbidity data are sometimes difficult to collect because of administrative clearance problems, and hard to interpret because of lack of diagnostic uniformity.

In order to give morbidity and mortality figures a proper frame of reference, certain other data should be collected. Date of occurrence is essential. Age of the individual, home address, place of employment, economic status, and previous medical history are of interest, because of the so-called "sensitivity" factors.

One of these factors is age. In order of decreasing sensitivity, according to a number of investigators (Reference 4-40) the age groups are:

(a) Over 65 years,
(b) Infants up to 1 year,
(c) 45-65 years,
(d) 1-12 years,
(e) 12-45 years.

People who smoke, people who have lived for years in heavily-industrialized areas, and people with a history of chronic lung, airway or heart malfunction also make up sensitive groups within the sampling population, (References 4-37, 4-38, 3-39, 4-40, 4-41, 4-46, 4-48, 4-49, 4-50, 4-51, 4-52, and 4-53).

4.4.3.2 Source of Data

Baseline data can usually be obtained from certain well-established sources, (References 4-41, 4-44, 4-50, 4-53, 4-54 and 4-55).

(a) Death certificates,
(b) Hospital admission records,
(c) Nursing homes,
(d) Pediatric, respiratory, and cardiovascular disease clinics,
(e) School absentee records,
(f) Sick-leave records from government and industry.

Continuing surveillance information may be obtained from volunteer panels established in key areas, as well as from the above (References 4-44, 4-49, 4-50 and 4-53).

4.4.3.3 Collection of Data

Three to five years' data are sufficient for establishment of a good baseline. In going too far into the past, major population shifts or sharp changes in the community's industrial complexion could contribute significant bias to the sampling outcome (References 4-41, 4-53, 4-54 and 4-60). Data collection forms should be uncomplicated documents which can be filled out with ease by anyone (References 4-38, 4-50, 4-54, and 4-55). The concepts of single-word or number descriptions and of checking the appropriate multi-choice selection should be used as much as possible. If the processing and analysis of the episode planning data are to be automated the forms should be designed for direct use as coding forms (Reference 4-50). Examples of suggested collection records are shown in Appendix G.

4.4.3.4 Data Processing and Analysis

The resolution of retrospective information into a baseline is an example of time-series analysis (References 4-42, 4-53, 4-56, 4-57, 4-58, and 4-59). It is the study of how some variable, or set of variables, changes with time. Such studies reveal cyclical movements which repeat themselves in a consistent and predictable pattern; seasonal fluctuations correlated to the time of year; upward or downward trends not related to cycles or seasons; and sporadic episodes or epidemics which override cycles, seasons and trends.

Morbidity and mortality are analyzed separately. First the data are tabulated by date. Second, a rate is calculated for each day and is usually expressed in number of cases or deaths per 1000, based on the concurrent area population. An excellent reference for population estimates is the "County and City Data Book," published yearly by the U.S. Bureau of the Census. Third, the daily rates are plotted against time so that cyclic, seasonal, and trend patterns can be detected visually.

Day-to-day variation produces a "rough" curve (Figure 4-13) (References 4-42, 4-53, 4-56, 4-57, 4-59, 4-61, and 4-62). Smoothing techniques can be simply "fitting by eye" -- or they can be processed by computer using one of the following fitting techniques which are described in Appendix D:

(a) The moving average (simplest of mathematical methods),
(b) Least-squares polynomial fit,
(c) Triple-exponential smoothing,
(d) Definition and application of a Fourier Series.

Approaches (b), (c) and (d) give an explicit function for the curve.

Some phenomena present in the rough curve may require attention before the baseline can be determined. One of these is the occurrence of "peaks," or extraordinarily large fluctuations not correlated with the seasonal or cyclic pattern (Figure 4-13). Such peaks may be due to epidemics, or even episodes, and should be excluded from the baseline. (References 4-56, 4-57, and 4-60.) Careful judgement must be exercised in an exclusion decision, so that bias is not introduced.

Data may exhibit a trend over the data time-span (Figure 4-14). If this condition appears, the slope of the trendline must be determined by regression analysis (References 4-56, 4-57, 4-59, and 4-61). If there is no significant trendline, the values for each day may be averaged, after exclusion of the peaks by a statistical or judgement procedure, to produce a one-year curve as a basis for the smoothing operation. In the case of a significant trend, the smoothing must be extended over the entire data collection time-span.

The next step is to calculate a critical level for the curve, the limit of mortality or morbidity which is normal for that date 95% of the time (References 4-56, 4-57, and 4-61). First, for each day in the time span

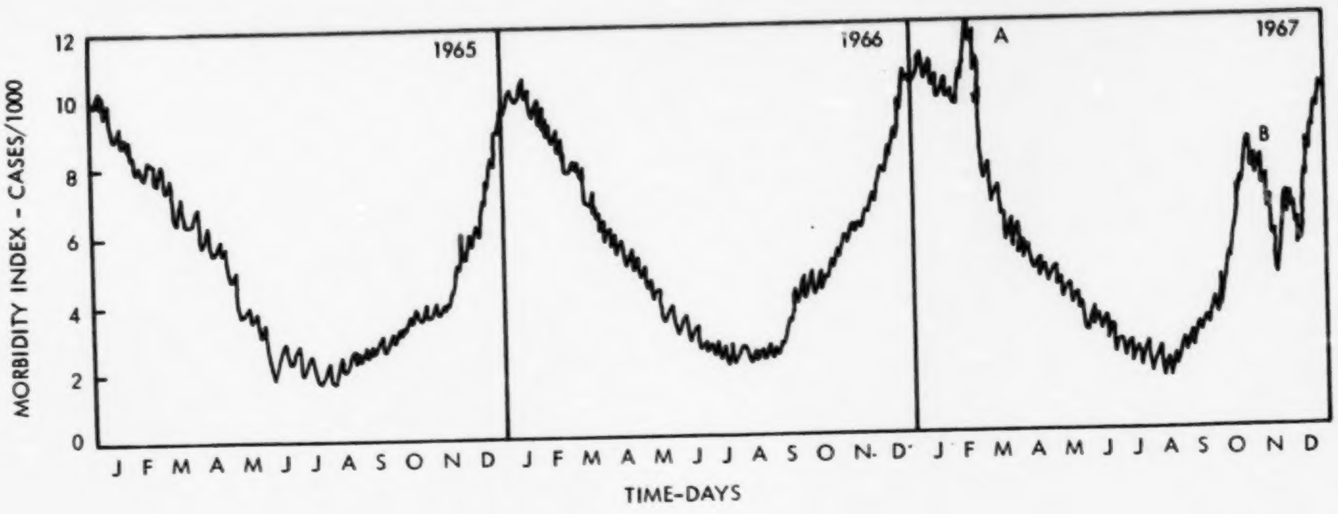


Figure 4-13. Plot of Raw Data (Note "Peaks" at A and B)

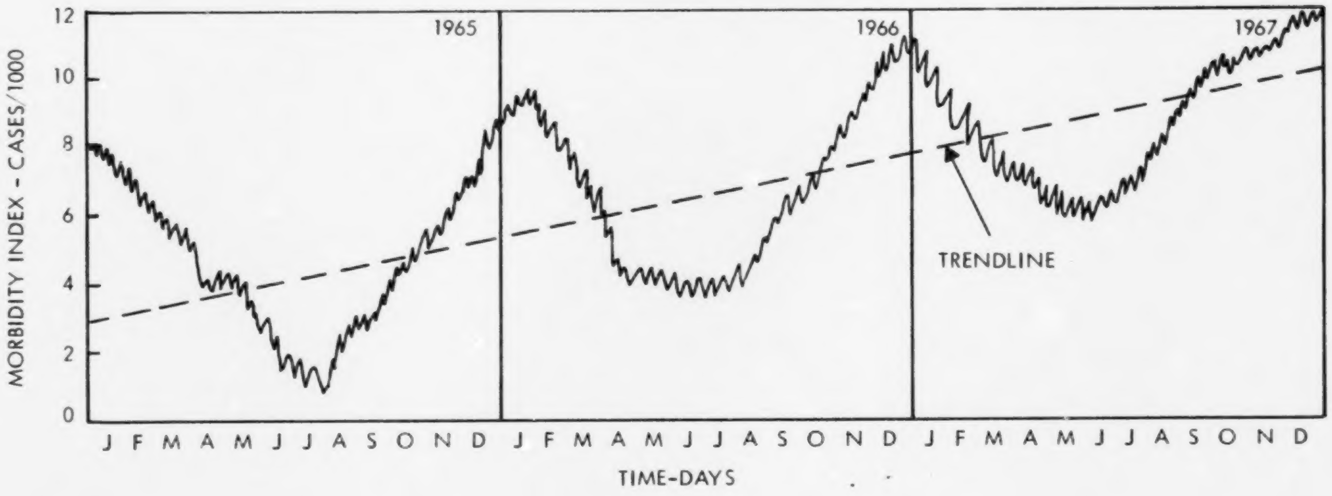


Figure 4-14. Plot of Raw Data Showing Trendline

determine its absolute difference from the expected value, that is, the fitted curve value. These are the daily fluctuations. Compute the mean and standard deviation for the daily fluctuations. See Appendix D.

Mean fluctuation plus (1.96 standard deviations) = the upper 95% confidence interval, or the highest fluctuation in the daily rate to be expected 95% of the time. Applying this confidence interval value to all the points on the fitted curve gives the critical level curve for the year (Figure 4-15).

The case where a significant trend is encountered requires that the regression function for the trend be used to arrive at the current year's operating curve before the critical level can be determined (References 4-56, 4-57 and 4-59).

If the daily morbidity and mortality rates are to be correlated with concurrent pollutant concentrations and meteorology the possibility of a time lag must be taken into account. The effect and causes may not be simultaneous. The statistical technique of cross-correlation can be applied in such situations. Coefficients for the correlation of atmospheric variables with mortality or morbidity 0, 1, 3, 4, etc., days later are computed to determine at what time-lag the most significant correlation occurs (References 4-42, 4-56, 4-59 and 4-61).

The calculation methods are described in detail in Appendix D. The maintenance of valid health effect information, whether for prediction or for historical purposes, requires that:

(a) The baseline be reexamined on a semi-annual (or at least annual basis) and adjusted to reflect the current information.

(b) The sampling source be improved whenever possible.

(c) "Key panel" chosen to supplant, or supplement the "total-data" concept used in acquiring the baseline, be truly representative of the original group, or reflect the current stratification of the area's population if supplementary.

(d) New techniques or considerations be incorporated into the sampling and analysis system as they appear.

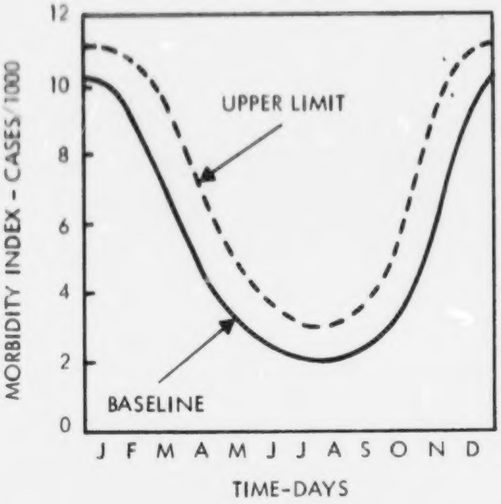


Figure 4-15. Smoothed Curve, Showing Upper 95% Confidence Limit

4.5 AIR POLLUTION MODELING

4.5.1 INTRODUCTION

Any equation is a model. The model tells the relations between its components. For instance, E = IR is a model familiar to nearly everyone. One value in it is that we can calculate results without making measurements, provided we have confidence in the model. In real life, measurements are always made to make sure the model predicts as accurately as required.

The term "modeling" is now used much more widely than ever before, probably because computers allow fast solution to complex problems. This has made easy and practical the study of complicated relations between variables; without computers, some problems would not be solvable in any useful time. Some aspects of model use and selection are discussed in Appendixes E and F.

In air quality work, seldom are enough samples collected to define atmospheric conditions satisfactorily. Even when sampling is thorough, that alone does not allow studying the effects of changing emission quantities, or estimating the probable effects of weather conditions other than those sampled, or both. Studies of this sort are desirable for understanding the state of the atmosphere in a given area, and to planning the necessary steps to avoid its deterioration.

The end result desired from a model to help with this descriptive problem is the capability to produce or simulate sampling results for any period of time under any meteorological conditions at any grid point. This would provide "total information" on the transport of pollutants to the receptors. Emission reduction costs and the effects on receptors are problems requiring other models; so actually a set of "interacting" models would be necessary to cover the fields of interest, with a different set for each pollutant permutation and combination.

Dispersion models for studying the fate of air pollutants have been under development since the 1930's and are now being studied intensively. Applications have been made for better technical understanding and for management decision-making; limitations are, mainly, lack of information on vertical wind and temperature structure, and on the effects of topography, including buildings. Health and economic effects models for air pollution work in a primitive state, by comparison.

4.5.2 USES OF MODELS

One of the major advantages of computer-based mathematical models is the ease with which large collections of data can be displayed in a variety of forms. An air sampling data point represents a single point at a single time in a given location. Mathematical models, on the other hand, can represent a continuum of data in time and in location. The data also can be easily processed to present it in the most convenient manner. To illustrate the point, let us consider a simple single source dispersion model, as described in Section 4.5.3.3. This model can be used to predict the distribution of pollutants over an area for a variety of conditions and for single and multiple sources.

The dosage for that distribution of pollutants can be represented, as shown in Figure 4-16. If the population density and a dose-response curve are known, the actual population affected by the pollutant could be estimated as shown in Figure 4-17.

No model set possessing all of these characteristics is presently available, but a number are being developed under sponsorship of the U. S. Department of Health, Education and Welfare.

Speaking of one model being jointly developed by the Chicago DAPC, DHEW and the Argonne National Laboratory, Mr. W. J. Stanley, Director of DAPC, Chicago, stated:

> "If such a computer program can be developed, three advantages will result:
>
> 1. It will be possible to forecast the severity of air pollution incidents with some degree of precision and to establish an effective pollution warning system.
> 2. It will be possible to develop economical and optimum air pollution abatement strategies to minimize the severity of pollution incidents. Such strategies would include switching major industrial or power plants which are equipped with dual fuel capability from coal to natural gas during severe pollution incidents and shifting of the electrical power load of Commonwealth Edison from upwind plants within the city to downwind or out-of-city plants. Other possibilities include the use of low sulfur content coal in nonconvertible plants, etc. To implement such a strategy at minimum cost and with minimum disruption of normal operations is one of the primary purposes of developing a computerized pollution forecasting method.

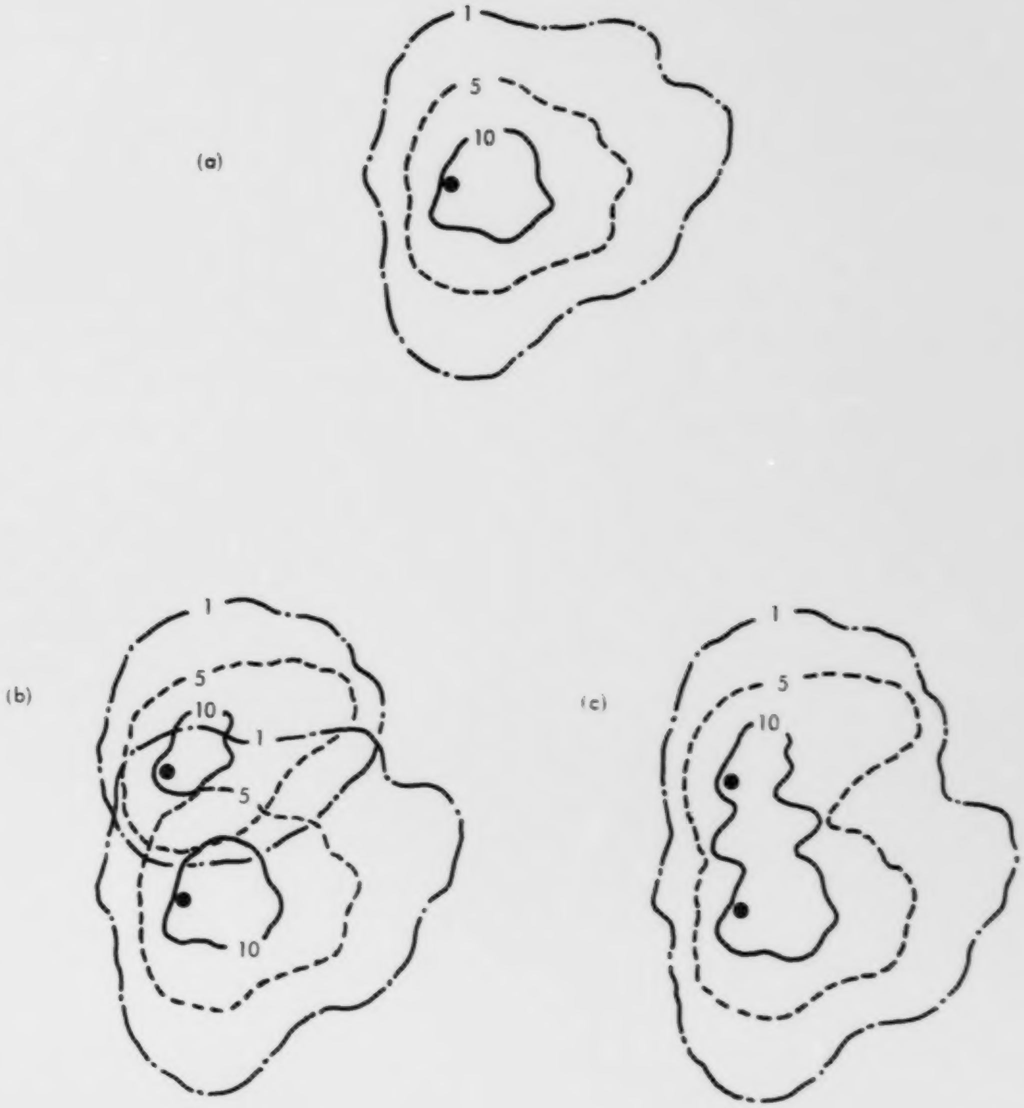
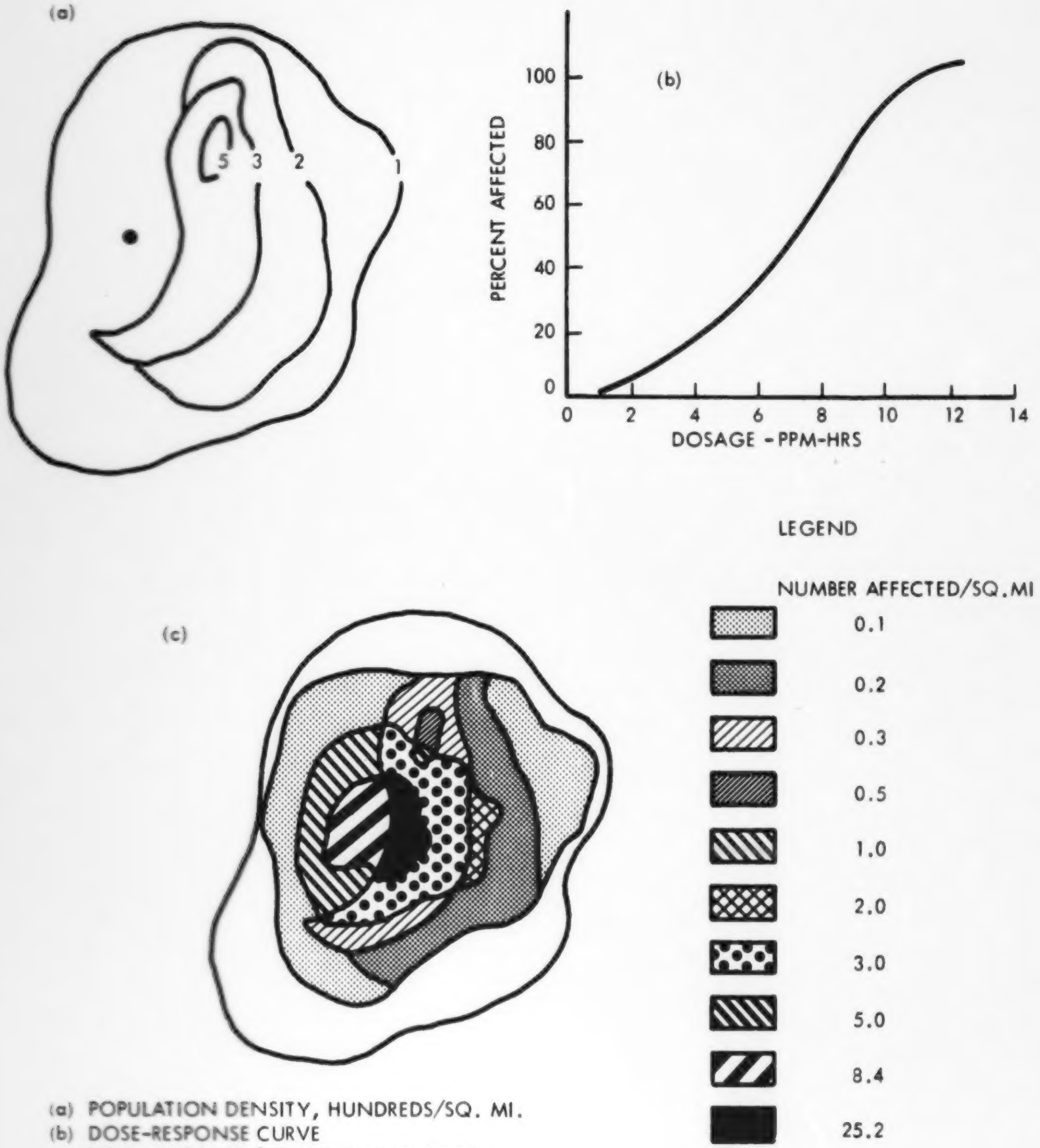

(a)
1
5
10
(b)
1
5
10
1
5
10
(c)
1
5
10

Figure 4-16. Dosage dispersion for a single source (a); two sources (b); and combined dispersion for two sources (c). Dosage units are expressed as ppm-hrs.



(a) POPULATION DENSITY, HUNDREDS/SQ. MI.
(b) DOSE-RESPONSE CURVE
(c) DOSE-RESPONSE/SQ. MI. USING DOSE-DISPERSION, POPULATION DENSITY, AND DOSE-RESPONSE CURVE

Figure 4-17. Estimated Population Affected by the Pollutant

3. Long-range city and county planning will be able to take account of the air pollution problem in the development of zoning ordinances and the layout of residential, industrial, and commercial areas. Pollution control legislation can be based on a realistic evaluation of the effects of various sources and control devices on the quality of Chicago's air."

4.5.3 ATMOSPHERIC DIFFUSION MODELS

A diffusion ("or dispersion") model is an attempt to represent mathematically a complex physical system. In this section a brief description of some existing models will be presented along with an outline of some of the factors the model is attempting to simulate.

4.5.3.1 The Dispersion Process

It is convenient to divide the description of the physical transfer of pollutants in the atmosphere into those motions resulting from large-scale air currents, and those due to the smaller-scale atmospheric turbulence. In the "normal" atmosphere, the contribution of atmospheric turbulence to the motion of pollutants is negligible in comparison to the contribution of the larger scale air currents along the direction of those air currents. The assumption is made, in most existing models, that the physical transfer can be treated as a combination of the transfer along the mean wind velocity vector (convection) and the motion in a plane perpendicular to the mean wind velocity vector (turbulent diffusion).

The pollutant transport process is influenced by a number of meteorological variables, the regional topography including structures, and by source characteristics and distribution.

The meteorological variables of major importance include:

(a) Wind speed and direction

(b) Atmospheric stability

(c) Mixing depth.

The wind velocity vector is fundamental to the convective transport mechanism. Wind speed also has an important influence upon the diffusion mechanism, since the greater the wind speed the greater is the level of atmospheric turbulence. This turbulence is a result of higher motion relative to the ground and to increased windshear.

The atmospheric stability is the major parameter in determining the turbulent quality of the atmosphere. Atmospheric stability is measured in terms of its temperature state. A mass of air rising in the atmosphere expands and is cooled adiabatically due to the decrease in pressure. The rate at which a mass of dry air (rising adiabatically) cools is called the "dry adiabatic lapse rate" (about 3°C/1000 ft). If the actual temperature gradient is greater than the adiabatic lapse rate, a rising eddy remains warmer than the surrounding air and continues to rise. Such an atmosphere is called unstable. Conversely, the atmosphere is stable when the temperature increases with height. In this case a rising eddy is colder than the surrounding air and its motion is thereby impeded. When the atmosphere is unstable, turbulence is at a maximum as the warm lower air rises. Under these conditions, the pollutants are more uniformly distributed in the mixing layer. Conversely, when the atmosphere is stable, pollutants tend to remain near the altitude of their introduction and surface emitted pollutants accumulate at ground levels. Atmospheric stability can be approximately quantified by defining a stability index, 1, 2, 3, 4, 5 corresponding to very unstable, neutral, stable or very stable atmospheric states, respectively.

The lapse rate itself is affected by the level of turbulence. Increased turbulence, due to atmospheric instability or to the presence of hills, trees, and buildings, tends to reduce the temperature gradients and stabilize the atmosphere. The heat generated by a city is a factor which promotes instability and generates turbulence.

The natural topography of a region not only effects pollutant transfer by creating and amplifying atmospheric turbulence, but also induces localized changes of wind direction and speed which can, in turn, create a channeling of the pollutants into local areas. Structures and foliage also contribute to ground level turbulence. Existing urban diffusion models neglect flow interference from buildings and natural topography. The problems of incorporating these effects in a model are difficult, which is the primary reason for the absence of these effects in current modeling approaches.

4.5.3.2 A Simple "Box" Model for Episodes

To illustrate one dispersion model, let us consider the following exceedingly simple case similar to that considered by Smith (Reference 4-47). The wind speed is quite low and a height (mixing depth) exists above which mixing does not occur. In addition, it has been observed that concentration gradients under these conditions are small. The basin under these conditions may be considered a box through which a wind is flowing, as shown in Figure 4-18. The pollutant emitted within the basin per unit time is designated Q, the uniform concentration of pollutants within the box, C, the mixing depth, h, the downwind length or fetch, w, and the wind velocity, v. Performing a simple material balance.

Pollutants in = Pollutants Out + Pollutants stored in box; or, for a box width, ℓ, at any instant of time,

$$Q = C\, v\, \ell\, h + \ell\, h\, w \frac{dc}{dt} \qquad \text{eq 1}$$

If the storage term is ignored, one obtains the steady-state concentration C_{ss}, namely:

$$C_{ss} = \frac{Q}{v \ell h} \qquad \text{eq 2}$$

The ratio between steady state concentrations for different conditions is then given by

$$\frac{C_{ss_1}}{C_{ss_2}} = \frac{Q_1 \; v_2 \; h_2}{Q_2 \; v_1 \; h_1} \qquad \text{eq 3}$$

This equation can be used to crudely predict the effect of changing meteorological conditions. For example, consider the following case: It is observed that with an 8 mph wind and a mixing depth of 3,000 ft. the concentration of SO_2 is 0.1 ppm. Predictions are that the wind speed will drop to 4 mph and the mixing depth to 1,000 ft. With no change in pollutant emission the steady-state concentration should rise to 0.6 ppm by applying eq 3. If it is desired to keep the SO_2 concentration below 0.3 ppm (possibly the First Alert level) the emission rate must be reduced 50%.

This, of course, assumes steady state conditions. To examine the transient conditions, combine equations one and two.

$$C_{ss_1} v_1 \ell h_1 = C v_2 \ell h_2 w \frac{dc}{dt} \qquad \text{eq 4}$$

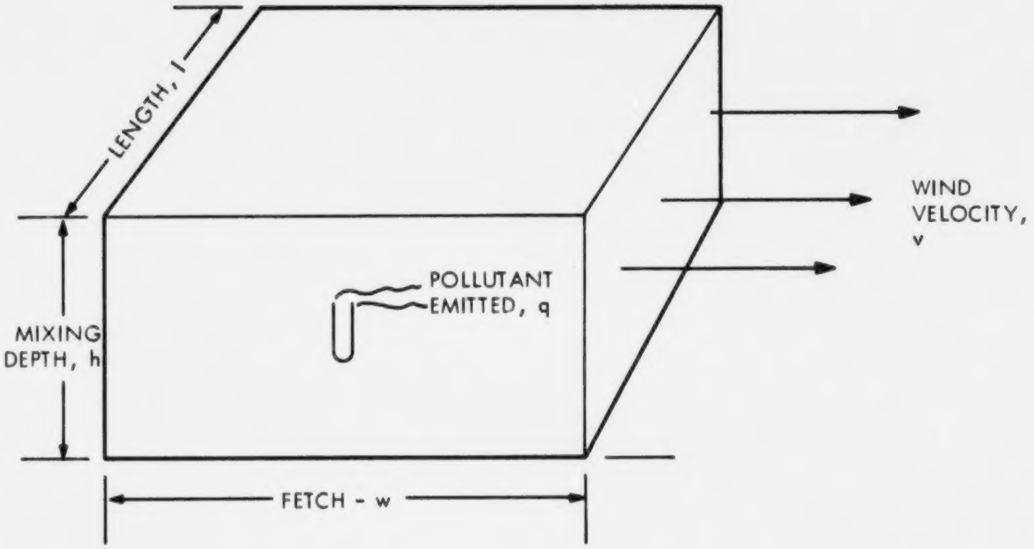

LENGTH, l
WIND VELOCITY, v
POLLUTANT EMITTED, q
MIXING DEPTH, h
FETCH - w

Figure 4-18. Box Model for Episodes

Assuming emission rate does not change ($Q_1 = Q_2$) and applying eq 3 and integrating one obtains

$$\frac{C(t) - C_{ss_2}}{C_{ss_1} - C_{ss_2}} = e^{-\left(\frac{w}{v_2} t\right)} \qquad \text{eq 5}$$

The time constant (time to reach 63% of the steady-state value) of the process is thus equal to the ratio of the downwind distance or fetch, w, and the wind velocity. In our sample case, assuming the fetch is 12 miles and the wind velocity is 4 mph, if the pollutant emission rate is not changed, it would take three hours for the concentration to reach 0.4 ppm. This is useful in giving the control agency a rough estimate of the time lags within the system.

The simple model illustrated would not be expected to give accurate results, ignoring as it does many of the physical realities of the true situation such as actual source location, non-uniformity in mixing depth, concentration distributions, wind velocity, vertical mixing, chemical reactions and topography. However, even if it is only accurate to ± 30% it does provide the control agency some useful information.

4.5.3.3 Review of Existing Diffusion Models with Particular Emphasis on Episode Prediction

Only a few diffusion models studied are urban models, i.e., models simulating an area with many types of sources; the others are models for studying diffusion from a single source. Considering only the urban models, we shall concentrate upon the following six identified by author:

Smith	Group I
Clarke	Group II
Miller and Holzworth	
Turner	
Koogler	Group III
Bowne	

These and other models are referenced in Appendix F.

The simplest model considered is that of Smith, which is similar to the "box" model presented in Section 4.5.3.1. Admittedly crude, this model is sometimes useful because of its simplicity, particularly if emission source characterization is not highly accurate. It can be used to predict transient effects and buildup during an episode.

The Group II urban models (Clarke's and Miller and Holzworth's) may be classified as "lumped" as they are concerned with overall values of source strengths and concentratrations for the area under consideration. The last three, Turner's, Koogler's, and Bowne's, may be classified as "distributed" since they take into account the spatial distribution of sources and concentrations.

The models belonging to Group I may be considered as "contained" in those of Group II in the sense that whatever can be calculated (or predicted) with Group I models can equally well be calculated (or predicted) with Group II models. Therefore, in the following, our discussion will only be concerned with models belonging to Group II.

We have three "distributed" urban models. Of these we shall not discuss the one by Turner since Koogler's model can be considered as a modified and improved version of Turner's model. It should, however, be recognized that Turner was the first to publish a reasonably realistic urban model and that later urban models have been based on his ideas.

The basic physical principles underlying the Koogler and Bowne models are essentially the same: The mass of pollutant emitted from a continous point source moves downwind at constant speed, at the time spreading horizontally and vertically in such fashion that while the mass in any cross section remains constant, the distribution of concentration of pollutant in this cross section along either the horizontal or vertical direction is bell-shaped, i.e., normal or Gaussian. The standard deviations of these two normal distributions are adjustable and increase with distance or travel time; they are the diffusion coefficients. The standard deviation of the horizontal distribution of pollutant concentrations is generally much greater than that of the vertical. Modifications for instantaneous sources and for several geometries are available.

The basic equation is the Gaussian equation presented below:

$$X_{x,y,z,H} = \frac{Q}{2\P\ \sigma_y\ \sigma_z\ \mu}\ \exp\left[-\ 1/2\left(\frac{y}{\sigma_y}\right)^2\right]\left\{\exp\left[-1/2\left(\frac{z-H}{\sigma_z}\right)^2\right]\right.$$

$$\left. +\ \exp\left[-1/2\left(\frac{2+H}{\sigma_z}\right)^2\right]\right\}$$

Q = Mass emission rate, g $\sec^{-1}$

π = Concentration, g m^{-3}

x = Downwind distance, m

y = Crosswind distance, m

z = Elevation, m

H = Height of plume centerline when essentially level, m

σ_y, σ_z = Standard deviations of plume concentration distribution in the horizontal and vertical, m

μ = Wind speed, m $\sec^{-1}$

One interesting point to note is that pollutant concentration is proportional to source strength and inversely proportional to the wind speed. At very low wind speeds the model can be in appreciable error. This leads to the use of a minimum wind velocity of 4-6 mph when using this equation.

Diffusion from area sources is described by suitably integrated forms of the above equation. Time-dependence of wind direction and magnitude, source strengths, and atmospheric stability are taken into account in what is usually known as a "quasi-stationary" approximation. By this we mean that the dynamic (transient) case is treated as a sequence of steady states.

The fact that any urban model based on the Gaussian plume formula simulates a dynamic or transient situation as a sequence of steady states has certain very important consequences. The conservation equation for pollutants states that the rate of accumulation of pollutant is equal to the net rate of inflow of pollutant minus the outflow due to transport and diffusion. The steady state approach implicit in the Gaussian plume models neglects accumulation or build-up during transients.

Episodes have always occurred under extraordinary meteorological conditions which reduced the effective volume of air in which the pollutants were diluted. These conditions involve the simultaneous occurrence of very light and variable winds, great stability and often fog at ground level for a period of several days.

The difference between episode pollutant transport and normal transport is that due to the low wind velocity, convective transport rate decreases and becomes closer to the diffusion transport rate. Further, the low inversion height and atmospheric stability reduce both the mixing volume and the diffusion rate.

Under these meteorological conditions, pollutants as they are emitted from a source are dispersed by atmospheric diffusion and by low velocity convection. In analyzing this situation, it is no longer possible to neglect diffusion transport in the downwind direction.

One conclusion of this review of existing diffusion models is that they have limited use for predicting episodal pollution build-up since:

(a) Episodes are a transient phenomenon, but existing models are for steady state conditions.

(b) Existing models are based upon assumptions, discussed above, which are not valid during episodes.

(c) Existing models are based upon correlations for the variances σ_y^2 and σ_z^2, which are not necessarily valid for episode conditions.

A bibliography of air pollution transport and diffusion models is presented in Appendix C.

4.5.4 OTHER MODELS USEFUL IN AIR POLLUTION CONTROL

The urban diffusion model is only one of many uses of computer-based mathematical models in the analysis of air pollution. Other models that can be useful in such analysis include:

(a) Source emission simulations,

(b) Statistical models correlating meteorology and pollutant concentration,

(c) Economic models,

(d) Dosage and health effect models,

(e) Adaptive models,

(f) Optimization models.

These will be briefly discussed in this section.

4.5.4.1 Source Emission Simulations

One of the basic tools in the control of air pollution episodes is source control. In some of the larger control agencies detailed real-time information is collected to determine the actual quantities of pollutants being emitted. As the number of sources is quite large, the source inventory may be "maintained" by a computer. In addition to maintaining the source inventory, the computer can be used to predict the results of control and curtailment actions. To accomplish this, the agency requires estimates of the time required by each source to accomplish control actions as well as estimates of emissions during the transient condition. Because of the large number of sources, "computerized" calculations are desirable. The use of computers allows the agency to examine combinations of different control actions to determine which will be most effective.

4.5.4.2 Statistical Models

The meteorological processes in the atmosphere are somewhat random and statistical or stochastic models can be developed which correlate meteorological variables with air pollution concentrations. This involves processing a large collection of data by means of regression analysis. The resulting regression equation becomes a prediction equation when present or future meteorological variables are used. Work along these lines has been done at New York University (Reference 4-63) and Los Angeles County Air Pollution Control District (Reference 4-64). The statistical approach may fall short in episode prediction, however, due to lack of episode data. (The regression equation predicts only on the basis of previous experience as contained in the regression coefficients.)

4.5.4.3 Economic Models

The objective of economic modeling is to simulate the impact on society of the implementation of an Emergency Action Plan. It is important to note that the number of cost elements described is not substantial argument to impede the adoption of emergency action plans, since human health is at stake.

While no models have been formulated and exercised for this purpose yet, it is likely that they will be developed. This discussion presents background necessary for exploring such modeling applications.

The purpose is comparison: To provide estimates of the comparative or relative costs of competing actions, and not to forecast the precise costs suitable for budget administration. Several ground rules are employed to develop an economic model:

(a) Major alternative action elements must be defined.

(b) Direct and indirect resource requirements attributable to these actions must be identified and expressed in terms of cost.

(c) Investment costs must be identified and distinguished from operating costs.

(d) Costs must be expressed as incremental costs so that only the relevant costs identifiable with a particular action are included.

(e) Time when each cost is incurred must be indicated.

(f) Costs should be expressed in consistent units (dollars).

Each affected industry or utility, etc. should establish its own direct cost estimating relationships for incremental costs. These costs typically include the investment cost, the operations costs, and the costs incurred as a result of an episodal event. Investment costs are the discounted equivalent annual costs to the industry for the purchase of capital items. Operations costs are annual costs which result from additional activities which are present because the industry must plan for emergency actions. Episode costs are those costs incurred from implementing the emergency actions in the event of a dangerous situation. The models of these costs are used by the control district to structure a preferred action plan and several alternates for each episode alarm and alert level.

Investment costs include the purchase of special emission control equipment such as scrubbers, precipitators and baghouses, etc. to process the emissions of the industry. They also include the construction of special facilities such as taller stacks and, as an example, equipment to provide for additional storage capacity for low sulfur fuels and for the storage of sensitive intermediate manufacturing products. Intermediate products may need to be stored if, as a part of the action plan, only a part of the manufacturing process is shut down. In this case, it may be desired to store these products to keep the rest of the process operating for some period of time during an episode.

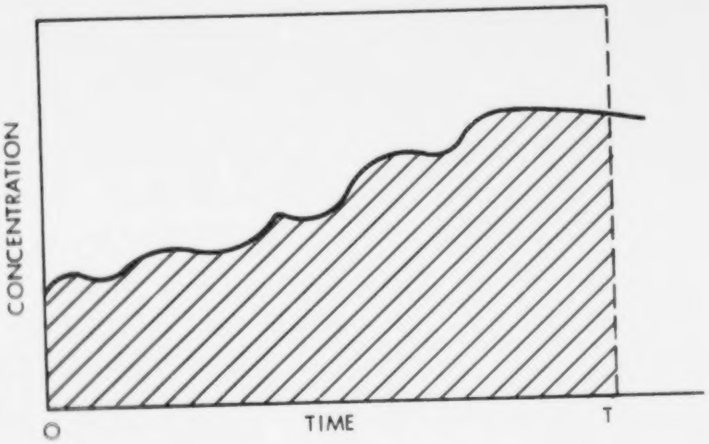
Operating costs include the direct costs of storage for the fuels and intermediate products. The costs also include the costs for performing process monitoring and maintaining the whole process in a suitable state of readiness to implement an Emergency Curtailment Plan, which may contain alternate procedures. Personnel must be trained to handle the emergency situation and they must also be available to coordinate with the control district when required; special personnel costs are considered operating costs.

Episode avoidance costs are those costs required to actually enact an Emergency Curtailment Plan. It includes damage to equipment, the fouling of processing equipment, the contamination of deterioration of products and the losses due to production stoppage. An additional factor which has to be considered is the time lost to the industry during the potential episode and the time required to re-start the process once the event is terminated.

There have been no general economic models published which adequately describe both the direct and indirect costs to society resulting from the planning for emergency action and the execution of the plans. It is presently feasible to model all the important costs using the direct cost estimating relationships generated by the industries concerned. There have been several published cost-effectiveness studies dealing with the air pollution problem. The economic models, however, do not usually possess the detail required for alternate action identification and evaluation for episode avoidance or else they deal with much larger economical situations not specific to air pollution. The techniques discussed in the current literature of the field of economic modeling are adaptable to the economic modeling of episode emergency action planning but they have not yet been applied. However, the development of the indirect cost models and the total-plan cost model are not yet a part of the state-of-the-art in air pollution episode avoidance analysis and planning.

4.5.4.4 Dosage and Health Effect Models

The purpose of emergency action planning for air pollution episodes is to protect the population. There are two principal factors in the determination of the effects of air pollution on the population: concentration of contaminant and time of exposure. Dose is defined as the product of the concentration and its exposure time. For a time-varying situation, an episode, the dose is the area under a time-concentration curve (see Figure 4-19).



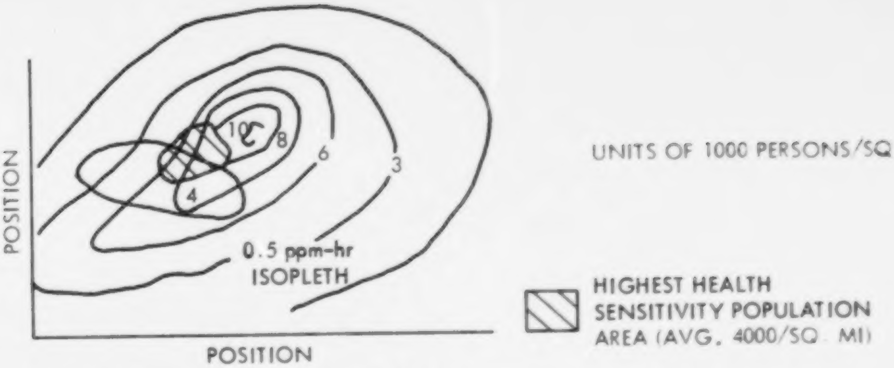
Note: Dose = Area

Figure 4-19. Concentration Buildup

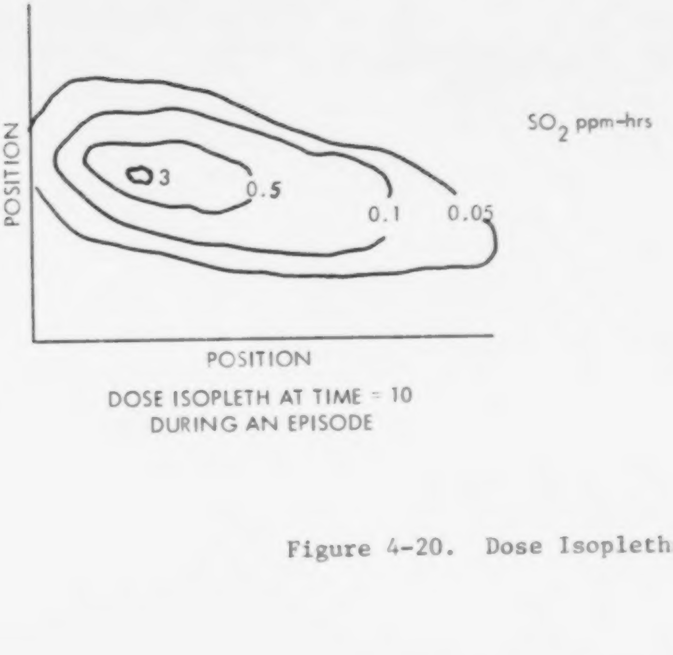
The model necessary to compute the dose consists of only the integration of concentration with respect to time.

The dose of each constituent may be computed to determine the effects on the exposed population. (The total effects are actually dependent on interactions of several pollutants, since the effects of the mixture are more severe than the sum of the effects of the pollutants taken individually.)

Integration of the concentration buildup over time at all the particular geographical positions of interest will generate the dose isopleths pictured in Figure 4-20. By superimposing these isopleths on the geographical distribution of the population, the number of people subjected to the various doses can be determined. Number of exposed individuals and dosage will indicate the number of people affected, if dose-response curves are available.


10
8
6
3
4
0.5 ppm-hr
ISOPLETH
POSITION
POSITION
UNITS OF 1000 PERSONS/SQ. MI
▨ HIGHEST HEALTH SENSITIVITY POPULATION AREA (AVG. 4000/SQ. MI)

URBAN POPULATION DISTRIBUTION OF NORMAL INDIVIDUALS


3
0.5
0.1
0.05
POSITION
POSITION
SO_2 ppm-hrs

DOSE ISOPLETH AT TIME = 10 DURING AN EPISODE

Figure 4-20. Dose Isopleths

Dose data should be computed and displayed to determine its distribution over the area of interest and also its time-dependent buildup to determine episode severity based on health effects. The required concentration information can be estimated coarsely with the models discussed earlier. The extrapolation of dose to the affected population is not routine and is not yet within the demonstrated state of the art.

4.5.4.5 Adaptive Programs

Many mathematical models incorporate variable coefficients in their equations. These coefficients are useful in "tuning" the model to the physical reality being simulated. For example, the plume dispersation model employs two such variables, σy and σz, which are modified to account for different stability conditions. These statistical estimators are based on observations and an adaptive model allows using continually-updated rather than fixed estimates. The aerospace industry has applied large computerized models employing adaptive procedures to the processing of data. The programs provide tuned models employing statistical analysis of the data to determine the best fit in real time for a large number of adjustable variables. While the techniques have not yet been applied to air pollution dispersion models, such application is to be expected in the near future. The result should be both an improvement of the dispersion models and a better understanding of the interrelationship of the variables. The mathematical techniques are discussed in Appendix E. Appendix F presents a method for selecting the appropriate models.

4.6 SOCIAL AND ECONOMIC FACTORS

4.6.1 SOCIAL CONSIDERATIONS

In the broadest sense, social considerations encompass all those factors which relate to human society, the welfare of human beings as members of society, and interaction of the individual and the group, and the cooperative and interdependent relationships of members of the group. Health and legal considerations are treated in other sections of this Manual. This section is restricted to a rather narrow field of human behavior, including pleasant or "social" companionship among individuals. There are several social factors which face the episode planner:

(a) First, he must realize that any action whatsoever that he takes will have a social effect;

(b) Generally, these effects will increase with the duration of the episode;

(c) Initially, the effects will usually be of the nature of inconveniences;

(d) The effects are primarily those related to restrictions on freedom of movement and on normal social activity, and the anxieties associated with a pervasive and malignant hazard from which there is no escape; and

(e) Finally, with some exceptions, these effects disappear at the termination of the episode.

The principal means available to the air pollution control authority to minimize these types of social effects is public education. The episode planner must provide for an effective public information program before, during and after an episode. The public must be prepared to endure the inconveniences of personal restrictions and to assess calmly the nature of the hazard.

The first social effects felt by the public will be relatively minor inconveniences resulting from voluntary compliance with appeals to reduce travel, postpone social functions and reduce the use of energy consuming devices (lighting, heating, cooling). While these inconveniences will be widespread, generally they are not sufficiently serious to become a major deterrent element in the implementation of the emergency plan. These classes of inconvenience become more serious as the episode continues. Before mandatory travel restrictions are applied, sufficient warning should be given to allow people to get home, to get food supplies and to perform other necessary and essential activities. This phase requires considerable care in both planning and execution. On one hand, panic must be avoided, because the pollution situation can be made worse through a sharp increase in traffic at this time. On the other hand, the long range deleterious effects of enforced immobilization and virtual isolation can be reduced through adequate preparation.

During the period of the emergency itself, the primary social effect is the direct threat to public health. Other effects which the planner must recognize are the increasing anxiety of the public, disturbances of domestic tranquility, requirements for emergency services (drug and food), increased loading of the telephone system, etc.

At the termination of the episode, most of these social effects (other than some health and economic factors) ease and disappear. However, the planner should provide for response to continued public and private clamor for adequate avoidance procedures, not only by being prepared to face recriminations but more importantly by planning to take advantage of constructive criticism and the sharpened public awareness of episode situations.

Surveys have been conducted in several cities exploring public attitudes toward air pollution. Generally, these surveys have been oriented toward the chronic situation in contrast to the episode condition. Based on a survey of Johnstown, Pa., Crowe (Ref. 4-65) concluded that the social characteristics having the greatest influence on a person's awareness and appreciation of the air pollution problem are level of education, social position, and location of present residence. DeGroot (Ref. 4-66), in reviewing six studies in an attempt to find trends in attitudes, found that health was the primary source for concern leading to awareness and that while all social characteristics have some influence on attitude formation, the preponderant determinant is the actual pollution level at the location of residence. He concluded that public education should emphasize what can be done and by whom, believing that further public dissemination of information that air pollution exists only raises the levels of anxiety and feelings of social impotence. Medalia (Ref. 4-67) studied an essentially one-industry community, Clarkston, Washington, in which awareness of the population problem was closely related to length of residence and occupation of the household head.

Under severe episode conditions, these findings may be expected to be biased in that everyone will be aware of the situation. The extent to which the people will define the condition as an individual or social (community) problem, on the other hand, may well parallel the findings of the chronic surveys. The civic air pollution control planner should conduct a survey of his area of concern to determine, beforehand, the public attitude in his specific case. Based on these findings, he should design his public education programs not only for the chronic situation but to minimize public and individual anxieties during an episode and, finally, he should plan to use the intensified post-episode awareness to improve the abatement program as may be appropriate to his community.

4.6.2 ECONOMIC CONSIDERATIONS

It is important to appreciate the fact that the benefits of improved air quality are as difficult to assess as are the many costs of air pollution control. As with any health-related affliction, the costs involve human factors that are difficult to express as equivalent dollars. For "episode control", the benefits include the avoidance of acute illness and death. The duration of much of the economic impact is a few days; when human lives are involved, the costs involved are relatively slight compared to the possible benefits. While several items of cost are discussed here, so that the Manual user will be better prepared to construct his plans, it is not suggested that these constitute substantive argument to impede the development of emergency action plans.

During the source inventory, information can be gathered which will assist the air pollution control agency in evaluating part of the economic impact of emergency action options. It is to industry's advantage to release accurate economic and emission data to help assure that designed actions are realistic and effective. The necessary information may be supplied voluntarily, or regulations may be required; both systems have their proponents. The control agency must scrupulously observe industrial proprietary rights to economic and technical information. Unless recovered pollutants are of economic value, there may be no objection to releasing pollution control cost data.

The economic impact includes costs to industry, direct costs to individuals and costs to the community. The discussion below is not exhaustive, and no weighting data are included to assess the significance of individual cost elements.

The costs of the episode to industry will be a combination of the fixed or regularly recurring costs associated with being prepared for an episode, and costs approximately proportional to the duration of the imposition of emergency abatement action during an episode. Both of these classes of costs will vary widely in magnitude and nature from place to place, among types of industries and among various plants within each industry. Consequently, data should be collected from each individual plant or plant classification.

4.6.2.1 Costs Related to the Maintenance of the Emergency Action Plans

In this category are included the costs to industry incurred in the compilation of data and with the formulation and updating of Emergency Action Plans. For most industries, these costs will be nominal.

4.6.2.2 Costs Related to Special Emergency Equipment

This category includes costs of plant equipment or other capital property required for emergency emission control. For actions such as fuel substitution, plant modifications, and fuel storage space and handling equipment costs are involved. This class of cost will be more significant in industries which cannot simply shut-down, such as power generation.

4.6.2.3 Direct Costs of Implementing the Emergency Control Action

Costs of modifying temporarily the normal activity of the plant include such items as investment in stockpiled low-sulfur fuel, special labor to curtail, shut-down or otherwise modify the activity, costs of uneconomic production runs, and products or processes damaged by shutting down. This class of cost may be significant in large industries having continuous high temperature processes.

4.6.2.4 Costs Related to Raw Material

The industry may have to plan for holding or diverting incoming raw materials during a period of curtailment or shut-down. Transportation during a severe episode will be severely curtalied, so some industries may be faced with storage problems.

4.6.2.5 Product Losses

These are costs proportional to the duration of the episode, such as extra costs for low-sulfur fuel, or losses in production during curtailment.

4.6.2.6 Sales Losses

Some sales losses such as transportation and amusements are absolute and cannot be made up by later deliveries. Many sales of products will be delayed rather than lost, but there may be some diseconomy from inability to fill outstanding orders.

4.6.2.7 Defaulted Contracts

Closely related to lost sales are the costs, in penalties, legal fees and future business, related to defaulted contracts. This may be remote because of the short time-span involved.

4.6.2.8 Costs Related to Employees

Some employees will be on salary which will continue through a shut-down; for others there could be wage losses during an episode shut-down.

4.6.2.9 Start-Up Costs

This class includes costs related to the recall of employees as well as direct costs of starting up the plant. These costs are similar to shut-down costs in that they are one-time, and may include such items as uneconomic production runs, periods of equipment inefficiency and abnormal material consumption.

4.6.2.10 Costs Related to Management

Costs related to management consist of time taken away from productive activities, either before, during or after the actual episode. There may be other factors, such as insurance, accounting and legal costs. Dealing with episodes, however, is but a small addition to management duties related to the conduct of business.

4.6.2.11 Costs to the control agency

The costs of an episode *per se* to the control agency are primarily those related to additional testing and surveillance and to 24-hour manning of the emergency control system. Most of the control system will be used for the "chronic" air pollution problem and not exclusively for episodes.

4.6.2.12 Miscellaneous Costs

There are additional costs which may be faced by a community. These costs include additional policing; extension of the school year; overtime for post-episode refuse disposal; losses in park vegetation, zoological specimens and similar items; and additional load on health agencies both during and after episodes and emergency deliveries of necessities. This class of costs is sensitive to the severity, duration and frequency of episodes, and may be relatively insignificant.

4.7 EMERGENCY CONTROL ACTIONS

Unfavorable meteorology, receptors, and emissions are the elements of air pollution episodes. Little can be done about meteorology, and receptor control actions are limited. Something can be done about emissions. This section reviews the control actions that are available.

4.7.1 CONTROLLABLE ELEMENTS AND CONTROL APPROACHES

4.7.1.1 Emission Source Control

To effectively curtail pollutant emissions, the control agency must know what emitters are controllable, the types and quantities of pollutants normally emitted, the time required to control the major emitters, and the effectiveness of the control action. Paragraph 4.3 contains the required background information. Typical controllable elements and control actions are illustrated in Figure 4-21.

4.7.1.1 Stationary Sources. Control of all stationary source emissions during a potential episode is probably impractical, but fuel shifting and curtailment of major sources can be accomplished. There are many possible strategies but the best approach will emerge through a consideration of the factors involved and the controls available.

Curtailment of operations can cause a temporary (but perhaps unimportant) increase in the pollutants emitted. Some sources will suffer irreparable damage if shut down completely. Each source or class of sources must be considered individually, but not necessarity in detail, by the control agency. Some general guidelines are available and are presented in this section.

The cost to the agency to perform a detailed analysis of each facility would be prohibitive. The operator of each major source will need to perform a curtailment or shutdown analysis of his facility with the agency providing guidelines. A formal Emergency Curtailment Plan should be prepared by each major source. This plan may or may not be submitted to the agency for approval, depending on local regulations. It should include both the expected results and timing of the action. The responsibility for economic evaluation of curtailment actions by major sources rests with each source. The agency should consult with the source or exercise enforcement powers where there are wide discrepancies between the effectiveness of the suggested curtailment and requirements for emission reduction.

CATEGORY	SOURCE TYPE	CURTAILMENT PLAN (f) DESIRABLE			SWITCH TO SULFUR FUEL			LOAD SHIFTING			LIMIT CLEANING AND START UP OPERATIONS			PLANNED PROCESS MODIFICATION			PARTIAL SHUTDOWN			START NO NEW BATCHES			REDUCE TO STANDBY			SHUTDOWN OR BAN			SELECTIVE SHUTDOWN			INCREASE ACTIVITY		
	ALERT LEVEL	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1		3	1	2	3	1	2	3
POWER GENERATION		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨		▨	▨																		
OTHER FUEL BURNING SOURCES	INDUSTRIAL	▨	▨	▨	▨	▨	▨				▨	▨		▨	▨	▨		▨	▨		▨	▨		▨	▨			▨						
	COMMERCIAL	▨	▨	▨	▨	▨					▨	▨						▨	▨		▨	▨		▨	▨			▨						
	PROCESSING	▨	▨	▨	▨	▨					▨	▨						▨	▨		▨	▨		▨	▨			▨						
	RESIDENTIAL				▨	▨	▨				▨	▨	▨					▨	▨															
INCINERATION	MUNICIPAL	▨	▨	▨													▨							▨				▨						
	COMMERCIAL	▨	▨	▨													▨							▨				▨						
	RESIDENTIAL																									▨	▨	▨						
	OPEN																									▨	▨	▨						
MANUFACTURING(a)	CONTINUOUS	▨	▨	▨	▨	▨	▨				▨	▨	▨	▨	▨	▨		▨	▨						▨			▨						
	BATCH PROCESS	▨	▨	▨	▨	▨	▨				▨	▨	▨	▨	▨	▨					▨	▨		▨	▨			▨						
COMMERCIAL(b)	ENTERTAINMENT	▨	▨	▨	▨	▨					▨	▨						▨										▨						
	OFFICE WORK	▨	▨	▨	▨	▨					▨	▨						▨										▨						
	BUSINESS	▨	▨	▨	▨	▨					▨	▨						▨										▨						
PROCESSING(c)		▨	▨	▨	▨	▨					▨	▨						▨										▨						
AGRICULTURAL	PROCESSING(d)	▨	▨	▨	▨	▨					▨	▨		▨	▨	▨		▨	▨						▨			▨						
	FIELD OPERATIONS(e)																						▨	▨	▨	▨	▨	▨						
GOVERNMENTAL	SCHOOLS																									▨	▨	▨						
	GENERAL OFFICE																									▨	▨	▨						
	PUBLIC SAFETY																															▨	▨	▨
CONSTRUCTION																					▨	▨					▨	▨						
ESSENTIAL FACILITIES	FOOD DISTRIBUTION																														▨			
	HOSPITAL & MEDICAL																															▨	▨	▨
	PHARMACIES																																	
	PUBLIC SAFETY																															▨	▨	▨
	COMMUNICATIONS																															▨	▨	▨
	NEWS MEDIA																															▨	▨	▨

(a) Manufacturing includes metallurgical, chemical, petroleum, mineral, paper, mining, etc.

(b) Commercial includes financial, stores, entertainment, offices, services, wholesalers, restaurants, etc.

(c) Processing includes laundries, dry cleaners, garages, service stations, food preparation, etc.

(d) Agricultural processing includes ginning, milling, feed and feed supplement processing.

(e) Agricultural field operations include spraying, dusting, field burning, grading, plowing.

(f) Size and emissions determine which commercial, processing, and agricultural plants must file plans.

Figure 4-21. Alternate Emergency Control Action

(a) Reduction of Emission Rates with Minor Changes in Throughput: A number of actions may be taken to reduce the quantity of emissions from industrial processes without appreciably affecting the overall throughput of the operation. These are typically steps which may be economically undesirable for normal operation, but which represent feasible operating modes during potential episodal conditions.

(1) Fuel Switching. Fuel switching is discussed in some detail in paragraph 4.3.4.2. Natural gas may be redistributed, considering costs, essential needs, and effects in "spreading out" emissions from higher-sulfur fuels. Considerable preplanning is necessary to establish the fuel switching alternative as a control measure.

Large consumers of coal or high-sulfur oil, such as power generating plants, central heating plants, and industrial plants may have dual-fuel capability for reasons other than air pollution control, making this alternative simply one of communication, of distributing available fuels, and of making provisions for stockpiling reserve supplies.

(2) Process Adjustment. The factors involved for some classes of industry are discussed in paragraph 4.3.4.3. The possibilities are practically endless, and must be explored for each pollutant source. If a control agency staff is available, cooperative analysis with the company engineers may turn up possibilities, but in a large city with thousands of sources, this is likely to be possible for only the major point sources. Any measure contributing to reduced exit loadings or to better dispersion is a candidate. Delay of certain noncritical functions, temporary (presumably less profitable) adjustment of control "set-points," and increasing stack temperatures or velocities are suggestions of possible general approaches to be investigated. Soot blowing, cleaning, and painting may be temporarily deferred.

(3) Load Shifting. The electric power industry must have excess capacity to handle peak demands and to provide for maintenance of equipment. During a potential episode it may be possible to shift the electrical load within and between power systems to reduce the quantity of pollutants emitted in a particular region. Typical actions here might include maximum use of hydroelectric power, shifting to plants utilizing low sulfur fuel, shifting to plants with superior pollutant removal or dispersion capability (scrubbers, taller stacks), shifting to more favorably located plants (downwind) and maximum use of nuclear plants. Load shifting by power companies must be a cooperative effort; reliance must be placed on power system engineers to exploit the available alternatives at the time of the incident.

(b) Reduction of Emission Rates by Curtailment of Operations: Curtailment of industrial and commercial operations without actual shutdown of the operation may sometimes represent the most effective means of reducing the quantity of pollutants emitted. General information is provided in Section 4.3.4.3. Care should be taken to assure that the curtailment will really result in an overall pollutant reduction. The purposes of such curtailment may include:

The reduction of pollutants directly emitted by the affected operation.

The reduction of power demands upon utilities to enable them to reduce their emissions.

The reduction of natural gas usage to enable gas to be used in more essential operations such as power generation.

The reduction of transportation requirements with resulting lower power demands and lower mobile-source emissions.

(1) Curtailment of Industrial Operations. Certain industrial operations cannot be shut down without major econimic loss. Typical of this type of operation is an aluminum reduction plant where complete shutdown results in solidification of the melt and partial fracture of the cell lining. In such cases curtailment of throughput may be the best strategy. By reducing the throughput and changing the process operating points, the emissions and power demands may be reduced with no danger of damage to the plant equipment. Another condition where curtailment may be more desirable than shutdown occurs in continuous petroleum or chemical process plants. To shut down such a plant it is necessary to dispose of the process material in columns, reactors, etc. This is sometimes accomplished by burning the material in a flare which could increase the emission of pollutants. Reducing throughput or even continuing normal operations might be the most desirable step. Obviously, the affected plants will be the best judge of which curtailment methods are feasible.

(2) Curtailment of Refuse Burning. In general, shutdown of a refuse burning installation will be desirable. However, at times, the storage capability of the plant will not permit shutdown for a period of days without creating a secondary health or nuisance problem. Under such circumstances a balance between reduced throughput and allowable storage of refuse may be the best solution, short of complete shutdown.

(3) Curtailment of Commercial Operations. Other than emissions due to heating, commercial operations are not usually a major source of emissions. In the early stages of an alert it may be desirable to request that

the comfort range for commercial operations be expanded to reduce heating and/or cooling loads.

(4) Curtailment of Residential Operations. Heating is the main source of residential emissions. Requests for voluntary reductions in heating by lowering the thermostat temperature and reducing power consumption by limiting lighting to, say, 40 watts per room, are among the few reasonable actions that can be taken, aside from the banning of backyard burning and barbeques.

(c) Reduction of Emissions by Shutdown of operations: Shutdown of industrial and commercial facilities is economically the most severe action that may be taken to curtail the emission of pollutants during a potential episode. Such shutdowns will require appreciable notice and planning. The development of Curtailment Plans as outlined in Section 4.3.4 is a necessary prerequisite to actual shutdowns. The net result of a general shutdown will be a gradual tapering off of pollutants emitted from the normal rate to standby or no-load operational levels. Not all facilities can or should be shut down. As previously mentioned, shutdown may in some cases result in a temporary (but perhaps unimportant) increase in pollutant emissions. Certain operations such as power generation, communications and medical facilities are essential and cannot be curtailed significantly; the latter two activities are likely to intensify, in fact.

A basic distinction can be made between batch and continuous operations. Because of the nature of a batch process, severe economic losses can sometimes be entailed by stopping the process during a batch. In general, the most reasonable curtailment action will be the prevention of starting of new batches. In some (probably few) cases it may be possible to "hold" a batch. The economic penalty must be weighed against the benefits in reduced emissions.

In addition to shutdown of facilities actually emitting pollutants, facilities which do not directly emit pollutants should be shutdown in many cases, where they indirectly contribute to pollution through power demands, natural gas usage and transportation requirements.

4.7.1.1.2 Control of Mobile Sources. The primary mobile source contributing to air pollution is the personal automobile. Control of automobile travel can be effected by voluntary, indirect and compulsory action.

(a) Voluntary Control: Requests can be made for voluntary curtailment of unnecessary automobile traffic. In Los Angeles, this approach has been tried, and the results have been poor. Another approach is for the employer to encourage the use of car pools and public transportation.

(b) Indirect Control: Indirect control of automobile traffic consists in making travel unnecessary or inconvenient. Closing down of facilities employing large numbers of people eliminates much of the travel to workplaces. Entertainment and retail business shutdown effectively limits many other trips. Closing down only main thoroughfares (freeways, turnpikes, etc.) and parking lots makes travel more difficult and less convenient. This is probably the most effective means of controlling automobile travel.

(c) Compulsory Control: A permit system can be established limiting travel on roads to those cars which have permits. Permits might be given, for example, to workers in mdeical, public safety, and other essential industries. All other travelers are given traffic tickets or warned to get off the roads. The enforcement problem would be extremely difficult.

4.7.1.2 Receptor Effect Control

Knowledge of air pollution health effects is not sufficient to suggest exactly the optimum behavior of individuals during potential episodes. One general rule is that individuals probably benefit by minimizing physical activities and remaining indoors. Individuals with respiratory and heart ailments should consult their doctors, insure that they have any needed medications and remain in areas that are pollution-free as much as possible. Medical authorities might consider placing extremely sensitive individuals in a hospital, or evacuating them to a "safe" area. It is important to realize that the alarm which could result from exaggeration of the dangers can be in itself dangerous. The control agency should be certain that announcements are cleared through advisory channels that appreciate this fact.

4.7.2 STRATEGIES FOR EMERGENCY CONTROL ACTION

4.7.2.1 Background

The emission source and source curtailment inventories described in Section 4.3 are the key to planning emergency control actions. Such inventories provide information for each pollutant source on

(a) Relative contribution of pollutants,
(b) Means of reducing pollutant emissions,
(c) Timing requirements of curtailment actions,
(d) The economic penalties of curtailment actions.

This information must be combined with local requirements for pollutant emission reduction to form the basis of a plan to control individual emitters during a potential episode.

The action taken should be that required to prevent any possibility of health damage to the population of the area. This is usually formulated as an alert system corresponding to different levels of required actions and potential health damage. Pollutant exposure units for these levels vary from agency to agency (see Section 3.4) but typically can be represented as shown in Table 4-6.

The emergency actions taken will be a graded response to the various alert levels, if possible (if vehicle exhaust is the main problem, only a single control action may be available). Actions can either be preset to correspond to the alert levels, or, in more sophisticated systems, flexible and dependent upon real time simulation of the episode.

In this section strategies for the control of pollutants during an episode will be presented ranging from the simple case of a single source to a highly sophisticated real-time simulation. Possible strategies along with required information are shown in Table 4-7. Each agency must evaluate its own problems and limitations to determine which plan of action is most suitable.

4.7.2.2 Simple Strategies

In certain localities the great bulk of the pollutants will be emitted by few large power generation or industrial processing plants. In such a situation the course of action centers about curtailing these large sources and a minimum of simulation is required. The plant or plants would be required to submit curtailment plans compatible with the required abatement for the different levels of alerts. Alternate actions to achieve these goals would be evaluated by the source and the agency serves only to accept or reject the suggested response.

In the typical situation there will be many sources emitting a variety of pollutants. While large sources such as power plants may contribute a large proportion of the pollutants, control of these sources alone may not be sufficient to prevent an episode. In addition, a variety of pollutants are involved and the system may involve interacting elements. For example it may be desirable to shift power generation from fuel oil to gas but sufficient gas may not be available unless certain industrial or commercial plants are closed down. Obviously a number of alternates must be considered.

TABLE 4-6

ALERT LEVEL[1]	STATUS[2]	CONDITION[1]
0	Forecast	High Air Pollution Potential Condition Forecast (Meteorology)
I	Alert	Approach to maximum allowable concentration. Still safe but approach a point where preventive action is needed.
II	Warning	Air Contamination Level at which a health menace exists in the preliminary state.
III	Emergency	Air Contamination at which a dangerous health menace exists.

1. Los Angeles County APCD Rule 156.
2. Status Criteria for a High Air Pollution Alert and Warning System Panel Report, December 1967, City College of New York.

TABLE 4-7

FACTORS CONSIDERED BY AGENCY

STRATEGY	SOURCE INVENTORY	SHUTDOWN PLANS	SOCIAL & ECONOMIC VALUE	DIFFUSION MODEL FOR PLANNING	REAL TIME DIFFUSION MODEL	REAL TIME ECONOMICS EFFECTS
SINGLE-SOURCE	X	X				
PROPORTIONAL PLAN	X	X				
SEQUENTIAL PLAN	X	X				
LEAST EFFECTS (STATIC)	X	X	X			
LEAST EFFECT (TRUE DOSAGE)	X	X	X	X		
REAL TIME LEAST EFFECT	X	X	X	X	X	X

The simplest approach is to: first, identify the emission rates and pollutants from each source (see Section 4.3); then, select an abatement strategy to reduce the pollution emission by fixed percentages for each alert level. For these purposed, ground level concentrations are considered proportional to emissions; cutting emissions by 1/3 cuts ground level concentrations by 1/3. Typical strategies not involving detailed simulation are included below.

4.7.2.2.1 Proportional Strategy. All sources must reduce emissions by the fixed percentages corresponding to different alert levels. This approach may be difficult to implement and can involve appreciable economic penalties.

4.7.2.2.2 Sequential Strategy. Selecting the largest controllable sources first, sequence control actions to give required reduction at each stage. For example, the first action might be fuel shifting at a power generation plant resulting in a 40% reduction in SO_2 emission. If the pollutant level continues to build up to alert level 2 the shutdown plans are implemented at the 10 to 30 next largest emitters and so on until the emissions are reduced by the desired percentage.

4.7.2.2.3 Cost-Effect (Approximate). In this approach the possible control actions are ranked on the basis of probably disturbance to the area's normal life and economy. This is a "static" determination, in that an estimate of the "costs and effects" is made a priori, and strategies are evolved well in advance of the episode. Control actions are selected to provide the desired reduction at each alert level, with the least disturbance (approximately) to the community. Some of the actions taken in the early alert phase may be requests for voluntary compliance, for example to restrict automobile traffic. As the episode progresses to more severe conditions the compliance would be mandatory and enforced.

It is apparent that the "cost-benefit" strategy is the best of those considered providing the curtailment survey has provided an adequate means of ranking the approximate effects of the control actions. To illustrate the strategy consider the hypothetical case shown in Table 4-8. For simplicity let us only consider one pollutant, SO_2, of which 200 tons/day are normally emitted, distributed as shown in the table. At this alert stage it is desired to achieve a 70% reduction in emissions. The actions

TABLE 4-8. COST-BENEFIT STRATEGY (SIMPLE)

Source	(tons/day)	Action Proposed Selected Action	Pollutant Reduction (tons/day)	Social Effect	Economic Effect
Power Generation	100	a) Shutdown Plant	100	Very high	Very high
		b) Switch to Remote plants	85	None	Moderate
	→	c) Switch to low sulfur fuel oil	70	None	Small
		d) Switch to natural gas	95	High[1]	Moderate[1]
Industrial Plant		a) Immediate Shutdown	15	Small	High
A (Batch Processing Plant)	20 →	b) No new batch starts	10	Small	Moderate
Industrial Plant		a) Immediate Shutdown	5	High[2]	High[2]
B (Continuous Petro Chemical)	5 →	b) Leave as is	0	None	None
Individual Incinerators	5 →	a) Immediate Shutdown	5	Small	None
Municipal Incinerators	20 →	a) Immediate Shutdown	20	None[3]	Small[3]
		b) Reduce throughput	10	None	Small
		c) Leave as is	0	None	None
Automobiles	20	a) Enforced restrictions on	15	High	High
	→	b) Voluntary restrictions on use	10	Moderate	Small
		c) Leave as is	None	None	None
Commercial Heating[4] & power	20	a) Shutdown completely	18	Moderate	Moderate
	→	b) Reduce workforce	12	Small	Small
		c) Leave as is			
School Heating[4]	10 →	a) Shutdown completely	9	Moderate	None
		b) Reduce length of day	6	Small	None
		c) Leave as is	0	None	None

---

1. Assumes that natural gas is being used for other activities such as residential heating, chemical plants etc. These operations would have to be curtailed to provide natural gas for power generation.
2. Plant may be damaged by action.
3. The incinerator can only backlog 4 days of refuse; social and economic penalties become severe if shut down for longer than this. Revert to reduced throughput at 3rd day of episode.
4. Reduction in power requirement further reduces emissions from power plant.

chosen to achieve this reduction are selected as the best approximate compromise between emission reductions and least economic and social effects. Obviously this case is appreciably simplified, though the footnotes to the table indicate a few of the interactions that might occur. The interactions make computer solution very appealing, but simple approximations are extremely useful and do not require special capabilities.

4.7.2.3 Analytical Cost-Effect Strategies

Much can be done to improve the simple cost-effect approach; if the problem justifies it, analytical tools can be developed and used to make strategy decisions. These tools may be applied in intermittent studies, that is prior to the episodal event; or, they may (eventually) be applied with "real-time" sensing and control in a near-time sense (actual automated control of sources appears patently impossible).

4.7.2.3.1 Intermittent Modeling. The purpose here is to use quantitative expressions to define and interrelate the same "effects" set out in the simple cost-effect approach. The ability to use models, once they are developed, to select best or optimum conditions (linear and other algorithmic programming, optimal adaptive adjustment, etc.) is refined and available systems engineering technique. To use these techniques, models describing economic effects, health effects, control costs and their interactions are necessary, and these are as yet only very approximate. Transport (dispersion) models are widely used for planning, and are being improved at a rapid pace.

The strategies in the previous section aimed to reduce the level of pollutants in the air by reduction of all of the inventoried emissions without regard to whether or not these emissions were contributing equally to the air pollution level. As shown in Section 3.5 the actual meteoroloty, local topography and location and height of emission sources can affect the impact of an emission in polluting the local atmosphere. By using effective source strengths* for emitters it is possible to simplify the accounting procedures for approximation purposes.

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* Effective source strength is defined as the quantity of pollutants emitted at ground level and zero velocity which would give the same rise in pollutant level as the source.

A dispersion model can be used effectively as a planning tool to evaluate alternate control actions. This permits the effectiveness of any given abatement strategy to be quantified a little better. Factors such as population distribution, dose-response, and diurnal cycles may be considered jointly with predictions of the dispersion model (see Section 4.5). Economic effects still have to be approximated.

By assuming various changes in emission rates, it is possible to examine the expected changes in exposure of receptors to pollutants; this can be quite simple or extremely complicated, depending on the amount of detail included. A distinction is drawn here between exercising the available tools on a "study" basis well before episodes occur, and providing actual sampling inputs to a computer which would analyze all the interrelationships and tell us what to do; clearly, there are actually a number of stages of sophistication in between. The purpose here is to illuminate some points in the spectrum of available and possible strategies to provide an overview.

4.7.2.3.2 "Real-Time Control". One problem with the strategies previously presented is that they are preset based on the expected pattern of a potential episode. As an episode is an uncommon event, the expected patterns may not be followed and actions may be taken too late or, conversely, be much more severe than required. A more flexible strategy would offer appreciable advantages provided there was a means to predict accurately the results of the control actions. Large scale computer-based management information systems are progressing to the point where this goal may soon be realized. The basic elements of such a program are shown in Figure 4-22. The elements include:

(a) Real-time (or nearly real-time) processing of meteorological and air sampling data.

(b) Local meteorological forecasts.

(c) Episode dispersion model including all local factors and simulating the effects of transient buildups.

(d) Real-time emission inventory and source location.

(e) Curtailment inventory including the time required for different actions by source class and location.

(f) Economic data showing the effects of the curtailment activities.

(g) Population distribution and dose-response data.

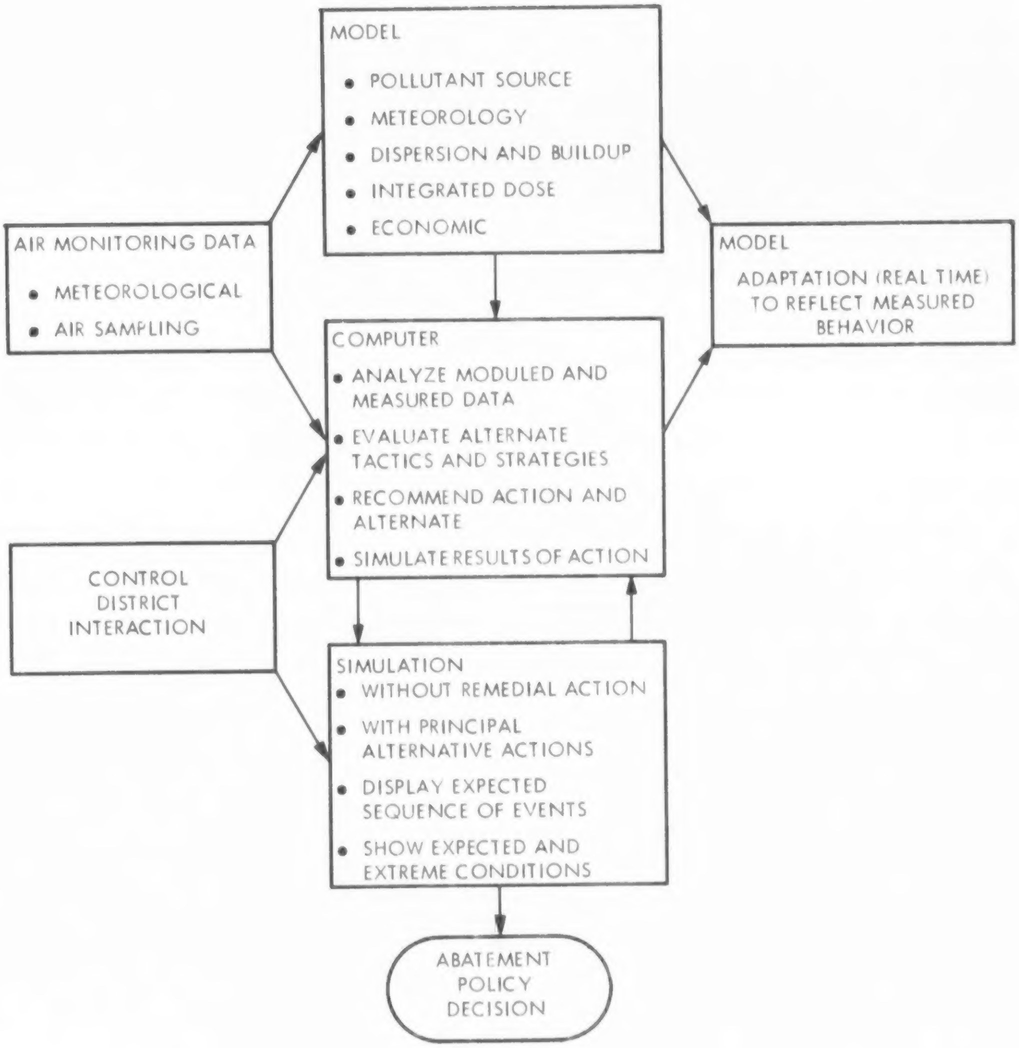

MODEL
POLLUTANT SOURCE
METEOROLOGY
DISPERSION AND BUILDUP
INTEGRATED DOSE
ECONOMIC
AIR MONITORING DATA
METEOROLOGICAL
AIR SAMPLING
MODEL
ADAPTATION (REAL TIME) TO REFLECT MEASURED BEHAVIOR
COMPUTER
ANALYZE MODULED AND MEASURED DATA
EVALUATE ALTERNATE TACTICS AND STRATEGIES
RECOMMEND ACTION AND ALTERNATE
SIMULATE RESULTS OF ACTION
CONTROL DISTRICT INTERACTION
SIMULATION
WITHOUT REMEDIAL ACTION
WITH PRINCIPAL ALTERNATIVE ACTIONS
DISPLAY EXPECTED SEQUENCE OF EVENTS
SHOW EXPECTED AND EXTREME CONDITIONS
ABATEMENT POLICY DECISION

Figure 4-22. Simulation and Modeling in Emergency Action Planning

One output of such a program could be the isopleths of receptor dosage as a function of time and control strategy as well as the economic cost of the various strategies. The agency could then in real-time project the results of alternate strategies, selecting the most cost-effective to maintain the population-dosage below a desired figure. Such programs are presently being developed in Chicago and by the National Center for Air Pollution Control. When they are generally available they will represent a powerful tool for the control of air pollution.

4.7.3 OTHER EMERGENCY CONTROL ACTION INFORMATION

Appendixes A and J contain additional data. Appendix A lists possible actions to be considered in implementing emergency criteria. Appendix J displays the New Jersey Emergency Control Actions currently under consideration.

4.8 COMMUNICATIONS

A well-planned information dissemination program serviced by an efficient communication system is essential to successful episode avoidance. To be effective, the information program must be developed and the communication system provided beforehand.

The "air pollution alert warning procedure" of Los Angeles is illustrated in the following diagram, Figure 4-23.

4.8.1 INFORMATION DISSEMINATION

A summary listing of the steps for dissemination of information within and outside the control agency for air pollution alerts follows.

The information channels involved with an air pollution alert will vary in each community. However, they are the same ones which are used in day to day communication between the control agency and the public.

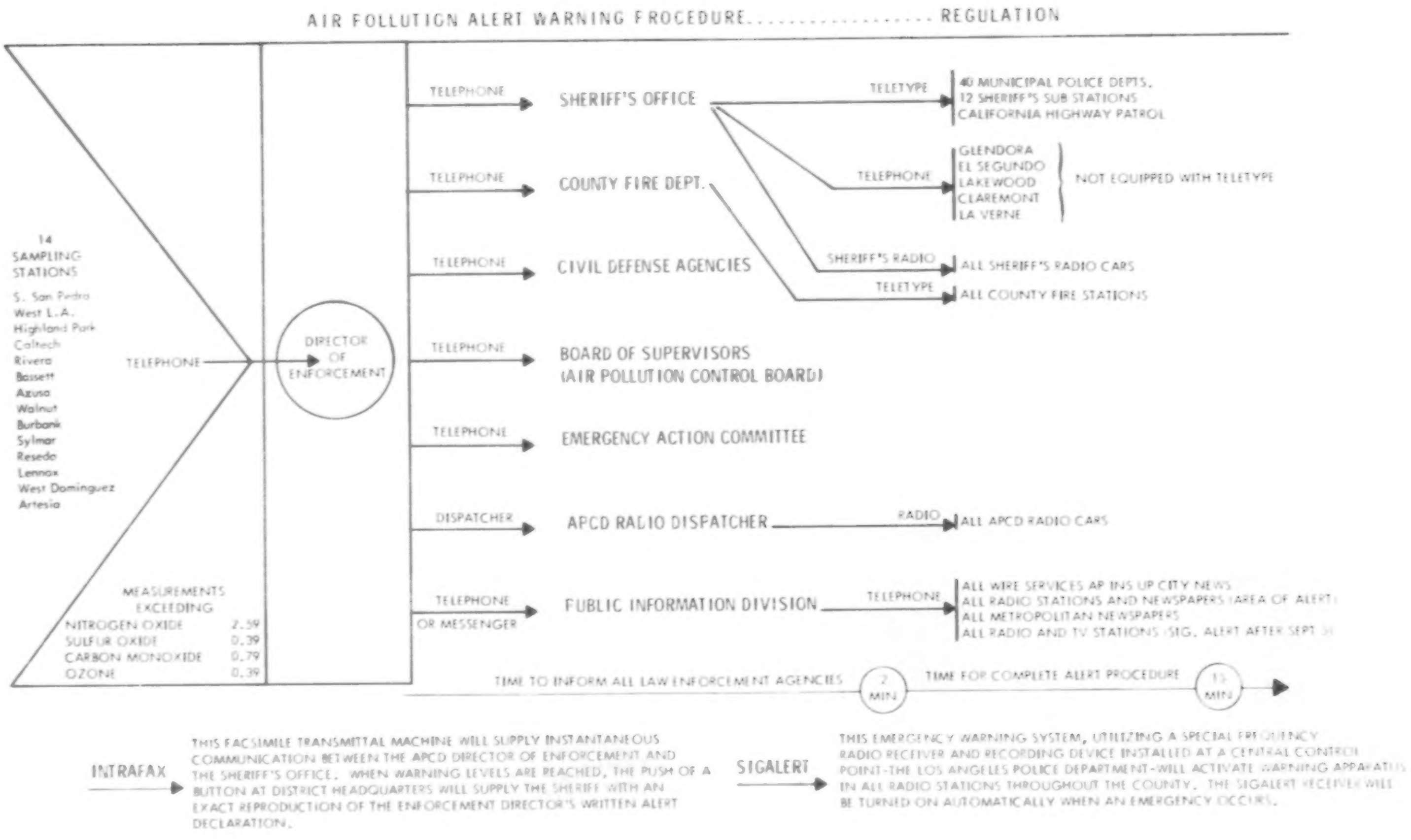
In order to achieve fullest cooperation during an episode, the public, which is affected by or contributes to high pollution levels, must be informed of what is expected of them during such conditions.

4.8.1.1 Information Programming Prior to an Alert

The air pollution control agency has the responsibility for generating all information and instructions as to what is expected and required of the public during an air pollution alert. To be most effective, this information should be developed and circulated prior to the occurrence of an episode, at least the information pertaining to alert levels actually expected to occur once in a while.

A program for the dissemination of air pollution alert information should include the following:

(a) Advance preparation of information covering the following:
    (1) Data which will cause the alert warning system to be activated.
    (2) Explanation of the various stages or levels of the alert.
    (3) Which actions are to be voluntary and which are required by law and at what stages of the alert.
    (4) What the individual can do to protect his family, his health and his property during each stage of an episode.



AIR POLLUTION ALERT WARNING PROCEDURE.................. REGULATION
14 SAMPLING STATIONS
S. San Pedro
West L.A.
Highland Park
Caltech
Rivera
Bassett
Azusa
Walnut
Burbank
Sylmar
Reseda
Lennox
West Dominguez
Artesia
TELEPHONE
MEASUREMENTS EXCEEDING
NITROGEN OXIDE 2.59
SULFUR OXIDE 0.39
CARBON MONOXIDE 0.79
OZONE 0.39
DIRECTOR OF ENFORCEMENT
TELEPHONE
SHERIFF'S OFFICE
TELEPHONE
COUNTY FIRE DEPT.
TELEPHONE
CIVIL DEFENSE AGENCIES
TELEPHONE
BOARD OF SUPERVISORS (AIR POLLUTION CONTROL BOARD)
TELEPHONE
EMERGENCY ACTION COMMITTEE
DISPATCHER
APCD RADIO DISPATCHER
TELEPHONE OR MESSENGER
PUBLIC INFORMATION DIVISION
TELETYPE
40 MUNICIPAL POLICE DEPTS.
12 SHERIFF'S SUB STATIONS
CALIFORNIA HIGHWAY PATROL
TELEPHONE
GLENDORA
EL SEGUNDO
LAKEWOOD
CLAREMONT
LA VERNE
NOT EQUIPPED WITH TELETYPE
SHERIFF'S RADIO
ALL SHERIFF'S RADIO CARS
TELETYPE
ALL COUNTY FIRE STATIONS
RADIO
ALL APCD RADIO CARS
TELEPHONE
ALL WIRE SERVICES AP INS UP CITY NEWS
ALL RADIO STATIONS AND NEWSPAPERS (AREA OF ALERT)
ALL METROPOLITAN NEWSPAPERS
ALL RADIO AND TV STATIONS (SIG. ALERT AFTER SEPT
TIME TO INFORM ALL LAW ENFORCEMENT AGENCIES
2 MIN
TIME FOR COMPLETE ALERT PROCEDURE
15 MIN
INTRAFAX
SIGALERT

INTRAFAX: THIS FACSIMILE TRANSMITTAL MACHINE WILL SUPPLY INSTANTANEOUS COMMUNICATION BETWEEN THE APCD DIRECTOR OF ENFORCEMENT AND THE SHERIFF'S OFFICE. WHEN WARNING LEVELS ARE REACHED, THE PUSH OF A BUTTON AT DISTRICT HEADQUARTERS WILL SUPPLY THE SHERIFF WITH AN EXACT REPRODUCTION OF THE ENFORCEMENT DIRECTOR'S WRITTEN ALERT DECLARATION.

SIGALERT: THIS EMERGENCY WARNING SYSTEM, UTILIZING A SPECIAL FREQUENCY RADIO RECEIVER AND RECORDING DEVICE INSTALLED AT A CENTRAL CONTROL POINT-THE LOS ANGELES POLICE DEPARTMENT-WILL ACTIVATE WARNING APPARATUS IN ALL RADIO STATIONS THROUGHOUT THE COUNTY. THE SIGALERT RECEIVER WILL BE TURNED ON AUTOMATICALLY WHEN AN EMERGENCY OCCURS.

Figure 4-23. Air Pollution Alert Warning Procedure

(b) Advance development of a program for dissemination of alert warnings.

(c) Establishment of priorities for the release of information during the alert.

Some of the primary tools for information dissemination available to an air pollution control agency are:

(a) Press Releases

The press release should be the primary means of communicating with the news media. All information released to the news media should be in the form of a press release, in order that a record of what has been said at what time and by whom is always available. Example press releases should be worked out ahead of time, and cleared through administrative channels. Typical press releases are shown as Figures 4-24 and 4-25 (Reference 4-68).

(b) Press Conferences

While the press conference provides an opportunity for officials to appear before news media, its use should be limited to very specific times and situations. If all the information can be contained in a press release, do not call a press conference. At press conferences visual information should be provided, e.g., samples of monitoring equipment, charts and graphs showing levels of pollution and weather conditions, photographs of the air pollution conditions, and photographs showing compliance with abatement provisions.

Several instances when a press conference can be useful in an episode information dissemination program are as follows:

(1) Announcing the Initial and Subsequent Stages of the Alert. A press conference is warranted at this time since the information to be given to news media is for the widest distribution and may be involved and detailed. It is suggested that representatives of the immediately and significantly affected segments of the government and industry be present at the press conference.

(2) Announcement of the Termination of the Alert. Since not all the episode effects information will have been developed at the time of the alert termination press conference, an announcement should be made as to when complete effects information will be available.

(3) Announcement of the Medical, Physiological, Sociological, Economics Effects of an Alert. This press conference may be held sometime following the alert. However, if it was announced at the "alert termination press conference" every effort should be made to hold it as soon as information is available. However, there may be an important "strategic" character in this planning

NEWS RELEASE - November 23, 1966

New York City
Department of Air Pollution Control
15 Park Row
New York City, New York

FOR IMMEDIATE RELEASE

CONTACT: Sy Mouber 566-8977

At 12:30 P.M. today (Wednesday, November 23, 1966), the local Weather Bureau notified the City's Department of Air Pollution Control that weather conditions consisting of a high pressure area and low wind speeds were developing in the metropolitan New York City area. These are the same weather conditions which are being formed over the Eastern seaboard from Maine to the Carolinas. These weather conditions are expected to continue until late tomorrow (Thursday, November 24) and may result in an increase in the levels of some air pollutants.

"There has been some increase in the levels of sulfur dioxide but the proportions of other contaminants have not reached a point where calling of an 'air pollution alert' is necessary or required," stated Austin Heller, Commissioner, New York City Department of Air Pollution Control.

Commissioner Heller also announced that the Air Pollution Control Department's laboratory at 121st Street had been placed on a 24-hour operational basis. Normally, the staff works a 40-hour week while the instruments measuring air quality record their results continually without attention around the clock. However, the Commissioner said, in order to be fully cognizant of the problems as they arise, we shall maintain a close watch on the conditions and report to the public if there is need for any specific activity. Mr. Abe Kussman, air pollution specialist for the New York City Weather Bureau, stated that because warm air was trapped by a lid of cooler, denser air, it would remain stagnant over the New York City area. It is expected that the Department of Air Pollution Control will issue another statement within 24 hours.

Figure 4-24. Sample Press Release

NEWS RELEASE - November 25, 1966

New York City
Department of Air Pollution Control
15 Park Row
New York City, New York

FOR IMMEDIATE RELEASE

CONTACT: Sy Mouber 566-8977

The first air pollution alert ever called in the City of New York was announced today (Friday, November 25, 1966) by Austin Heller, Commissioner of the New York City Department of Air Pollution Control. At a press conference held in the City Hall, presided over by Deputy Mayor Robert Price, the following statement was issued by Commissioner Heller:

"As you know, we are now in the first alert stage. I want to acquaint you with the steps already taken and those additional steps I would like you to undertake immediately.

"We have the full cooperation of Consolidated Edison in that they will use as much natural gas as possible. They have been doing so since Wednesday evening. I talked with Mr. W. D. Crawford, Consolidated Edison's Vice President, this morning and have his assurance that they will continue further. They will have available some interruptable gas from Brooklyn Union Gas Company and will reach into their own storage facilities.

"Mr. H. O'Neill of Long Island Lighting Corporation has on a voluntary basis made a major change in the fuel use pattern and are using as much natural gas as they have available to them.

"The City's incinerators are shut down and will continue to stay down until further notice.

"I am asking the citizens of New York City to take three steps:

"1. First, cease permanently the operation of all private apartment house incinerators until further notice.

"2. I am recommending for all apartment houses and commercial use where number six fuel oil or soft coal are used that the

Figure 4-25. Sample Press Release

indoor temperature be reduced 10 degrees--as an example, from 70°F to 60°F. This will be a major contribution in the control of sulfur dioxide.

"3. I request that the citizens of New York and those living in the metropolitan area use their personal automobiles only when absolutely necessary. Further, I wish to call upon the owners and operators of trucks and other vehicles to curtail, if possible, the use of these vehicles during this period of concern.

"Immediately when I receive notice that the weather conditions have changed and the levels of contamination begin to return to satisfactory levels, I shall return to you with an announcement in order that you might return to normal operation.

"I have been in constant communication with Mr. Thomas Glenn of the Interstate Sanitation Commission; Mr. Al Rihm, Jr., Assistant Commissioner for Air Resources for the State of New York; and upon firm consideration have decided that the calling of this first alert was absolutely necessary.

"While we have no specific required activities under our present alert program, the cooperation of all citizens is urged," stated Commissioner Heller.

Figure 4-25. Sample Press Release (Continued)

function; insuring that all considerations are balanced will be a responsibility of the pollution control officer and other responsible government and industry officials.

(c) Telephone Calls

The commercial telephone system will be a primary means for information dissemination to governmental agencies, large emission sources and other individual recipients. Where volume indicates, direct lines may be arranged for use during emergency periods.

(d) Television and Radio Interviews

Every effort should be made to comply with requests for specific radio and television interviews. While the radio and television interviewer will be interested specifically in the conditions of the alert, every effort should be made by the air pollution control agency representative to include information concerning the agency's and industry's day to day operation and concern for the public welfare.

(e) Letters of Inquiry

Every air pollution control agency receives letters of inquiry from the public to his community. These letters are one of the best barometers an air pollution control agency can have in determining the public attitude toward air pollution control and afford an opportunity for dissemination of information to interested citizens.

(f) Medical Societies and Hospital Associations

Medical societies can be of outstanding service by creating and disseminating meaningful information to physicians concerned with respiratory and cardiac patients. Aiding in the development of health studies related to episodes can be a specific function of these organizations.

(g) Speaking Dates

A presentation should be prepared for use by control agency speakers for use at civic meetings.

(h) Schools

The aid of the Board of Education can be enlisted for the distribution of literature by students to their homes.

(i) Mailings

Although the postage costs can represent a major item, this means of distribution can be used effectively just before an "episode season," if desired. Public relations advice is generally available.

(j) Radio-Dispatcher Vehicles

Radio-dispatched municipal vehicles and taxis can be located at strategic points to constitute an emergency radio net.

4.8.1.2 Information Dissemination During an Alert

Upon notification of a potential episode, the air pollution control agency should have ready for activation the episode information plan. The following guidance for an information program to be used during an air pollution alert should be adapted to fit the needs and capabilities of the local agency. However, it is essential that an information plan be developed in advance which can be put into motion upon receipt of an APPF advisory. The elements of such a plan are unique, although the plan utilizes the same channels of communication and the same tools of information dissemination which are used in day to day information programming.

When the local air pollution control agency receives an APPF advisory from the weather bureau either by phone or on the ESSA local weather loop, those in the air pollution control agency responsible for implementing emergency action are notified. After a decision is made that alert conditions exist, the lines of communication are:

(a) The news media are informed that an air pollution alert has been called and that within the next forecast period (usually six hours) additional information will be released. Immediate contact is necessary since the news media are on the local weather circuit and will have already received the APPF advisory. Since many of the major sources of air pollution are also on the ESSA weather loop they will have received this information at the same time the news media received it.

(b) The next series of notifications is made to those activities which may be affected by the initial alert and to those which must muster support forces or make mechanical or operational changes in their industrial processes to meet the requirements of the various levels of the alert system. This notification will probably be by telephone.

(c) The news media should be the primary means of communication with the general public as subsequent stages of the alert are reached. The announcement of what each of the various affected segments of the general public will be required to do can best be communicated through the news media. The news media in announcing various alert stages have been reached would also announce what emergency actions are to be taken.

See Appendix B for more detail information of the local weather loop used in the cities of New York and Los Angeles.

4.8.1.3 Information Dissemination Following an Alert

Dissemination of information following an alert can serve to clarify misunderstandings which arose during the alert. In addition, information can be disseminated which will result in a better overall air pollution control program and more effective episode avoidance system. The analysis and evaluation of information collected during the episode may require considerable time. The channels of communications for post-alert information are the same as those available to the control agency for information developed prior to and during the alert. An important item of information which, hopefully, the control agency can disseminate in the post-alert period is public recognition of the cooperation received from other government agencies and from those segments of industry and the public which were affected.

4.8.1.4 Public Education

Public education on air pollution should be a continuing objective. During air pollution episodes, short, to-the-point messages should be prepared for public distribution. The messages may be disseminated by television and newspapers, or by posters and flyers. The following flyer, published by the National Tuberculosis and Respiratory Disease Association, is a good example of such a message (Figure 4-26).

4.8.2 COMMUNICATION SYSTEM PLANNING (Reference 4-69)

4.8.2.1 Objective

The general objective of any communication system is to provide the facilities to handle the peak message traffic with reasonably small delay, at minimum expense. Consideration of the following will aid in providing an adequate system at reasonable cost.

The primary factors which control the choice of the facilities are the volume, type and time distribution of the information and a determination as to what constitutes "reasonably small delay."

4.8.2.2 User Considerations

The air pollution control agency will furnish the above factors to the engineer who is to either design or arrange for the communication system or services. This engineer may be part of the air pollution control agency inself or a communications specialist obtained for this purpose. To "research" the problem, the following questions should be answered for the specific local situation under episodic conditions:

Figure 4-26

WHEN AIR POLLUTION IS HEAVY

Here's what you can do to help yourself and your neighbor

- Use public transportation wherever possible. Use your automobile only if absolutely necessary. If you must drive, try to team up with neighbors or co-workers.

AIR POLLUTION FROM AUTOMOBILES
IS A MAJOR PROBLEM

- Reduce room temperatures to the legal minimum, unless health considerations prevent such action.

AIR POLLUTION FROM HEATING EQUIPMENT
IS A MAJOR PROBLEM

- Stop all outdoor burning.

AIR POLLUTION FROM OPEN OR REFUSE BURNING
IS A MAJOR PROBLEM

- Use as little electricity as possible, either for lighting or appliances.

AIR POLLUTION FROM POWER PLANTS
IS A MAJOR PROBLEM

- Observe the restrictions recommended by your health department or air pollution control agency.

IF YOU SUFFER FROM A RESPIRATORY AILMENT OR HEART CONDITION--

Remain indoors with the windows closed.

Don't smoke. Avoid rooms where others are smoking.

Eliminate unnecessary physical exertion.

Stay under your physician's care.

AIR POLLUTION CONTRIBUTES TO RESPIRATORY DISEASE

(Published by the National Tuberculosis and Respiratory Disease Association)

(a) Why does the agency need to transmit information?
    (1) To obtain data upon which to base action plans,
    (2) To obtain authority to implement actions,
    (3) To implement actions,
    (4) To obtain cooperation of the public.

(b) What information does the agency need to transmit?
    (1) Public education information,
    (2) Technical information,
    (3) Instructions on emergency actions,
    (4) Status reports during an episode,
    (5) Critiques of episode avoidance action,
    (6) Public relations information.

(c) With whom does the agency need to communicate?
    (1) Subordinate elements of the agency,
    (2) Government agencies,
    (3) General public,
    (4) Significant emission sources,
    (5) Meteorological agencies,
    (6) Public safety and health agencies,
    (7) News media.

(d) Where is the information to be disseminated?
    (1) Primarily within the jurisdictional area,
    (2) Adjacent areas,
    (3) State capital,
    (4) Federal regional air pollution control headquarters.

(e) What are the time elements?
    (1) Before an episode, low urgency,
    (2) During an episode, high urgency,
    (3) After an episode, low urgency.

(f) What are the available means?
    (1) Commercial wire and radio systems,
    (2) Private wire or radio systems,
    (3) Public news media,
    (4) Mailings and posters,
    (5) Civic meetings and school presentations,

(6) Medical societies and health organizations,
(7) Technical symposia and journals.

4.8.2.3 Properties of Communication Traffic

Communication traffic has common properties which are more or less independent of the mechanism of transmission. The communications specialist will evaluate the information volume, type and time factors listed in the preceding section against such properties in order to specify the general communication system parameters.

Information to be transmitted is usually in the form of groups of related bits. These groups or information pieces are called messages. For example, a numerical reading from a remote sensor, a telephone conversation or a complete technical journal article each constitute a message.

The following properties of messages affect the specification of a communication system:

(a) Space
  (1) Locations of origin and destination(s),
  (2) Distances between origin and destination(s),
  (3) Paths between origin and destination(s),
  (4) Physical dimensions of origin and destination(s).

(b) Time
  (1) Starting time,
  (2) Duration,
  (3) Completion time.

(c) Information Properties
  (1) Languages or codes used,
  (2) Statistical or semantical content,
  (3) Redundancy,
  (4) Information rate.

(d) Physical Properties
  (1) Kinds of wave phenomena,
  (2) Wave or pulse properties used to encode,
  (3) Methods of transmission (sequential, parallel, etc.),
  (4) Correlation between input and output(s),

(5) Frequency band or time slot location of signals,

(6) Frequency spectra.

During transmission, the messages are subject to attenuation, delay, distortion and interference to relative degrees dependent upon the specific system.

4.8.2.4 Guidelines for System Planning

Once the properties of the information traffic have been determined, the general system parameters can be outlined. As a minimum, the outline should include the following items:

(a) Specification of the kind of messages: e.g., telephone, telegraph, facsimile, digital, video or documents.

(b) Switched or non-switched network. Most messages will not require direct full-time lines.

(c) Message capacities among the terminals of the network.

(d) Insurance against information loss in transmission.

(e) Reliability and ease of installation, maintenance and operation.

(f) Demand for privacy only to the degree required. Most messages will not require privacy at all.

(g) Cost-effectiveness measures. Expensive nice-to-have features should be kept to minimum.

(h) Satisfaction to the users at both ends. The communication means should be compatible to the normal practices of the recipients of the messages. For example, mailing a news release of immediate interest or telephoning a long technical paper would be equally inappropriate.

Depending upon the nature and quantity of the messages, the jurisdictional area and the availability of common-user communication services, the system complexity and size will vary widely from city to city. In most cases, a combination of means: messenger, commercial telephone, radio, wire services, etc., will be used. In some cases, dedicated (that is, single user) systems will be appropriate for those applications where service on a non-interference basis is required. Such instances may be data lines to key monitoring stations and emergency communications to large emission sources.

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APPENDIX A

A LISTING OF POSSIBLE ACTIONS TO BE TAKEN IN IMPLEMENTING EMERGENCY SITUATION CRITERIA

1. Prohibit open burning of trash, leaves, paper or demolitions debris.

2. Prohibit the use of municipal, home, commercial, governmental, institutional, or industrial incinerators. If possible, extinguish incinerator fires or if not practical bank such fires.

3. Delay the start-up of new industrial equipment.

4. Postpone industrial plant start-ups and shut-downs.

5. Boiler lancing or soot blowing should be done only when absolutely necessary and should be scheduled to take advantage of the best meteorological conditions. Between 1 and 3 p.m. is probably most logical.

6. Industrial processes which emit either/or sulfur dioxide or fly ash should be reduced to half rated plant capacity.

7. Reduce the consumption of all heating fuel by decreasing the indoor temperature to the minimum comfort level.

8. Request that all motor vehicles operators reduce their activities to a minimum.

9. Impose on the general population brown-out conditions comparable to those used during war time.

10. Prohibit motor vehicle travel including trucks and busses except the emergency vehicles.

11. Close down commercial, retail, industrial, etc. establishments.

12. Prohibit the cleaning of storage vessels containing toxic or odorous compounds.

13. Make mandatory that batch operations discharging SO_2 be closed down.

14. Make mandatory that bituminous coal users burning more than 200 tons of coal annually switch to low sulfur coal (1% or less).

15. Make mandatory that all residual oil consumers who use more than 500,000 gallons of residual oil annually switch to low sulfur oil (1% sulfur oil or less).

16. Make mandatory that natural gas be burned in those industries and power generating facilities where gas is in ready supply and equipment is available.

17. Make mandatory that all power generating facilities and all industrial units have a 5-day supply of low-sulfur fuels (1% or less) available for consumption at all times. This would apply to any boiler or aggregate of boilers in one location whose rated hourly capacity or summed hourly capacity equals or exceeds 200,000 pounds of steam hourly.

18. Ask that all power generating plants and major industries submit to the Department for review and approval their emergency action plans.

APPENDIX B

THE LOCAL WEATHER LOOP

B.1 INTRODUCTION

The local U. S. Weather Bureau station's weather loop, in some instances, has become a major link for disseminating information concerning periods of high-level stagnation.

B.2 NEW YORK CITY, NEW YORK (METROPOLITAN AREA)

When the NMC (A) transmits an APP to the local New York City weather bureau, this information is telephoned by the Weather Bureau to the following individual organizations:

(a) The Interstate Sanitation Commission,
(b) The City of New York,
(c) The State of New York,
(d) The State of New Jersey,
(e) The State of Connecticut,
(f) Certain counties on Long Island,
(g) The State of Pennsylvania (if certain eastern Pennsylvania counties are effected).

Representatives of four of these organizations (a, b, c and d) will then meet as an advisory board in the offices of the Interstate Sanitation Commission to receive, review and evaluate data from various air pollution monitoring stations. This board has no powers of enforcement, but serves in an advisory capacity to keep the representative organizations aware of developing conditions.

The transmission of the APP over the local weather loop is delayed 45 minutes in New York City by unofficial agreement between the weather bureau and the various air pollution control agencies in the metropolitan area.

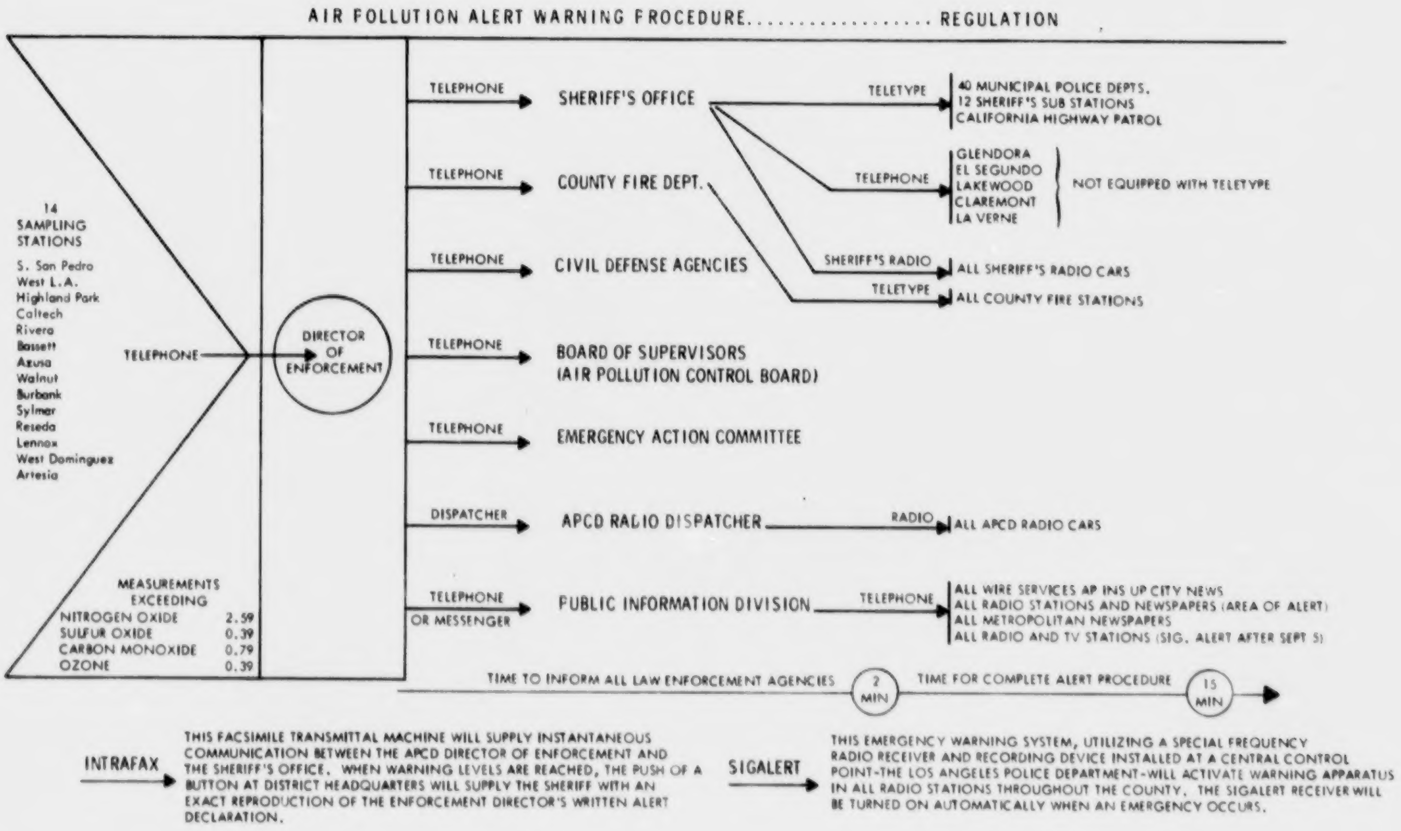
Contact between the news media is not directed through a central agency, but rather is handled separately by the local air pollution control agencies.

B.3 LOS ANGELES COUNTY AIR POLLUTION CONTROL DISTRICT

The Los Angeles County Air Pollution Control District has developed a comprehensive weather and air pollution forecasting competency. However, the District's weather office receives weather information from the local Los Angeles weather loop. They use the local weather circuit information for comparison with their own forecasts, predictions, and in many of their research projects.

Since they are part of the local weather loop, there is no particular elapsed time between the weather bureau transmission of an APP advisory to the air pollution control district. However notification of alert warnings is handled by the Public Information Division of the District.

The District is proud of its record in putting an alert into force. To cover all the various agencies and information media involved requires about 15 minutes. (See Figure B-1.) Dissemination to such a wide and varied group of agencies and organizations could not be accomplished in this short time if considerable effort and emphasis had not been placed on the overall information program.


AIR POLLUTION ALERT WARNING PROCEDURE.................. REGULATION
14 SAMPLING STATIONS
S. San Pedro
West L.A.
Highland Park
Caltech
Rivera
Bassett
Azusa
Walnut
Burbank
Sylmar
Reseda
Lennox
West Dominguez
Artesia
TELEPHONE
MEASUREMENTS EXCEEDING
NITROGEN OXIDE 2.59
SULFUR OXIDE 0.39
CARBON MONOXIDE 0.79
OZONE 0.39
DIRECTOR OF ENFORCEMENT
TELEPHONE
SHERIFF'S OFFICE
TELEPHONE
COUNTY FIRE DEPT.
TELEPHONE
CIVIL DEFENSE AGENCIES
TELEPHONE
BOARD OF SUPERVISORS (AIR POLLUTION CONTROL BOARD)
TELEPHONE
EMERGENCY ACTION COMMITTEE
DISPATCHER
APCD RADIO DISPATCHER
TELEPHONE OR MESSENGER
PUBLIC INFORMATION DIVISION
TELETYPE
40 MUNICIPAL POLICE DEPTS.
12 SHERIFF'S SUB STATIONS
CALIFORNIA HIGHWAY PATROL
TELEPHONE
GLENDORA
EL SEGUNDO
LAKEWOOD
CLAREMONT
LA VERNE
NOT EQUIPPED WITH TELETYPE
SHERIFF'S RADIO
ALL SHERIFF'S RADIO CARS
TELETYPE
ALL COUNTY FIRE STATIONS
RADIO
ALL APCD RADIO CARS
TELEPHONE
ALL WIRE SERVICES AP INS UP CITY NEWS
ALL RADIO STATIONS AND NEWSPAPERS (AREA OF ALERT)
ALL METROPOLITAN NEWSPAPERS
ALL RADIO AND TV STATIONS (SIG. ALERT AFTER SEPT 5)
TIME TO INFORM ALL LAW ENFORCEMENT AGENCIES
2 MIN
TIME FOR COMPLETE ALERT PROCEDURE
15 MIN
INTRAFAX
SIGALERT

INTRAFAX THIS FACSIMILE TRANSMITTAL MACHINE WILL SUPPLY INSTANTANEOUS COMMUNICATION BETWEEN THE APCD DIRECTOR OF ENFORCEMENT AND THE SHERIFF'S OFFICE. WHEN WARNING LEVELS ARE REACHED, THE PUSH OF A BUTTON AT DISTRICT HEADQUARTERS WILL SUPPLY THE SHERIFF WITH AN EXACT REPRODUCTION OF THE ENFORCEMENT DIRECTOR'S WRITTEN ALERT DECLARATION.

SIGALERT THIS EMERGENCY WARNING SYSTEM, UTILIZING A SPECIAL FREQUENCY RADIO RECEIVER AND RECORDING DEVICE INSTALLED AT A CENTRAL CONTROL POINT-THE LOS ANGELES POLICE DEPARTMENT-WILL ACTIVATE WARNING APPARATUS IN ALL RADIO STATIONS THROUGHOUT THE COUNTY. THE SIGALERT RECEIVER WILL BE TURNED ON AUTOMATICALLY WHEN AN EMERGENCY OCCURS.

Figure B-1. Air Pollution Alert Warning Procedure

APPENDIX C

AIR POLLUTION MODELS

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APPENDIX D

HEALTH STATISTICS

D.1 SMOOTHING TIME-SERIES BY THE MOVING AVERAGE METHOD (Ref. D-1)

Let $X_t, \ldots, X_n$ represent an array of data points in a time-series where the units of time are $t = 1, 2, 3, \ldots, n$. An arbitrarily-based subset of X-values are chosen to be averaged about some midpoint, X_t. For example:

$$\bar{X}_4 = (X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7)/7$$

$$\bar{X}_5 = (X_2 + X_3 + X_4 + X_5 + X_6 + X_7 + X_8)/7$$

$$\bar{X}_6 = (X_3 + \ldots\ldots + X_9)/7$$

$$\vdots$$

$$\dot{\bar{X}}_n = (X_{n-3} + X_{n-2} + X_{n-1} + X_n + X_1 + X_2 + X_3)/7$$

The $\bar{X}_t$'s shown above might well be those calculated for a one-year array, with a subset base of seven days. The choice of subset base (usually an odd number) is predicated upon the variation seen in the raw data; that is, some judgment must be exercised so that genuine cycles, trends, or seasonal patterns are not obscured in the process.

D.2 LEAST-SQUARES FIT OF A POLYNOMIAL REGRESSION FUNCTION (Ref. D-2)

This procedure fits to the data a k-degree polynomial function of the type:

$$Y = \beta_o + \beta_1 X + \beta_2 X^2 + \ldots + \beta_k X^k$$

A system of linear equations is developed and solved for the value of $b_o, b_1, \ldots, b_k$, which are the estimators of $\beta_o, \beta_1, \ldots, \beta_k$. The equations take the form:

$$
\begin{aligned}
\Sigma Y_i &= nb_o + b_1\Sigma X_i + \cdots + b_k\Sigma X^k \\
\Sigma X_i Y_i &= b_o\Sigma X_i + b_1\Sigma X_i^2 + \cdots + b_k\Sigma X_i^{k+1} \\
&\;\vdots \\
\Sigma X_i^k Y_i &= b_o\Sigma X_i^k + b_1\Sigma X_i^{k+1} + \cdots + b_k\Sigma X_i^{2k}
\end{aligned}
\qquad (1)
$$

where all summations extend from 1 to n.

The coefficients of the right-hand terms in these equations may then be represented in a matrix:

$$
B = \begin{matrix}
n & \Sigma X_i & \Sigma X_i^2 & \cdots & \Sigma X_i^k \\
\Sigma X_i & \Sigma X_i^2 & \Sigma X_i^3 & \cdots & \Sigma X_i^{k+1} \\
\cdot & & & & \\
\cdot & & & & \\
\cdot & & & & \\
\Sigma X_i^k & \Sigma X_i^{k+1} & \Sigma X_i^{k+2} & \cdots & \Sigma X_i^{2k}
\end{matrix}
\qquad (2)
$$

If the determinant of this matrix, $\Delta = B$, is not equal to 0, then the values for b_j ($j = 0, 1, \ldots, k$) may be found by the equations:

$$
b_j = \frac{1}{\Delta}\;
\begin{array}{l}
\text{Matrix B with the elements of the} \\
\text{(j + 1)th column replaced by the} \\
\text{corresponding elements from the} \\
\text{left side of equation system (1).}
\end{array}
\qquad j = 0, \ldots, k \qquad (3)
$$

To demonstrate, consider the solution of a 2nd-degree polynomial, $Y = b_o + b_1X + b_2X^2$, letting r, s, and t stand for the columns of matrix B, 1, 2, and 3 for its rows, and d_1, d_2, and d_3 for the left-hand terms of equation system (1). The equations for the b_j are:

$$b_o = \frac{\begin{matrix} d_1 & s_1 & t_1 \\ d_2 & s_2 & t_2 \\ d_2 & s_3 & t_3 \end{matrix}}{\begin{matrix} r_1 & s_1 & t_1 \\ r_2 & s_2 & t_2 \\ r_3 & s_3 & t_3 \end{matrix}} ; \quad b_1 = \frac{\begin{matrix} r_1 & d_1 & t_1 \\ r_2 & d_2 & t_2 \\ r_3 & d_3 & t_3 \end{matrix}}{\begin{matrix} r_1 & s_1 & t_1 \\ r_2 & s_2 & t_2 \\ r_3 & s_3 & t_3 \end{matrix}} ; \quad b_2 = \frac{\begin{matrix} r_1 & s_1 & d_1 \\ r_2 & s_2 & d_2 \\ r_3 & s_3 & d_3 \end{matrix}}{\begin{matrix} r_1 & s_1 & t_1 \\ r_2 & s_2 & t_2 \\ r_3 & s_3 & t_3 \end{matrix}} \qquad (4)$$

Solving these matrix systems:

$$b_o = \frac{d_1s_2t_3 + s_1t_2d_3 + t_1d_2s_3 - d_3s_2t_1 - s_3t_2d_1 - t_3d_2s_1}{(r_1s_2t_3 + s_1t_2r_3 + t_1r_2s_3 - r_3s_2t_1 - s_3t_2r_1 - t_3r_2s_1 = \Delta)} \qquad (5)$$

$$b_1 = \frac{r_1d_2t_3 + d_1t_2r_3 + t_1r_2d_3 - r_3d_2t_1 - d_3t_2r_1 - t_3r_2d_1}{\Delta} \qquad (6)$$

$$b_2 = \frac{r_1s_2d_3 + s_1d_2r_3 + d_1r_2s_3 - r_3s_2d_1 - s_3d_2r_1 - d_3r_2s_1}{\Delta} \qquad (7)$$

When $k > 2$, manual calculation becomes increasingly more cumbersome as k becomes larger, and the investigator is advised to avail himself of a computer for $k \geq 5$.

Another solution method for polynomials is that of multiple regression, which provides error terms and tests of significance for the b_j, as well as for the regression equation. The reader is directed to Reference No. 20 for detailed discussions of this technique as well as the one shown above.

D.3 TRIPLE EXPONENTIAL SMOOTHING FOR TIME-SERIES (Ref. D-3)

This technique produces a smoothed series $s_1, s_2, \ldots, s_n$ for a given time series $X_1, X_2, \ldots, X_n$ and a given smoothing constant, α:

where $0 < \alpha < 1.0$.

The initial values of the smoothing coefficients are obtained:

$$C_1 = X_1 - 2X_2 + X_3 \qquad (1)$$

$$B_1 = X_2 - X_1 - 1.5C_1 \qquad (2)$$

$$A_1 = X_1 - B_1 - 0.5C_1 \qquad (3)$$

The smoothed value for s_1 is calculated:

$$s_1 = A_1 + B_1 + 0.5C_1 \tag{4}$$

The coefficients are updated:

$$A_i = X_i + (1-\alpha)^3 (s_{i-1} - X_i) \tag{5}$$

$$B_i = B_{i-1} + C_{i-1} - 1.5(\alpha)^2 (2-\alpha) (s_{i-1} - X_i) \tag{6}$$

$$C_i = C_{i-1} - (\alpha)^3 (S_{i-1} - X_i) \tag{7}$$

The smoothed value, s_i, is calculated:

$$s_i = A_i + B_i + 0.5C_i \tag{8}$$

Equations (5) through (8) are repeated sequentially for $i = 2, 3, \ldots,$ n.

D.4 A RECURSIVE SOLUTION FOR A FOURIER SERIES (Ref. D-4)

This technique calculates the Fourier coefficients, a_o, a_k, and b_k of a tabulated function:

$$Y_i = f(x) = a_o + \sum_{k=1}^{m} [(a_k)(\cos\lambda_k X_i) + (b_k)(\sin\lambda_k X_i)]$$

where m = the desired order of the series

t = the number of data points $(i = 1, \ldots, t)$

$\lambda_k = \frac{2\pi k}{t}$

The calculations are as follows:

$$C_1 = \cos \frac{2\pi}{t} \tag{1}$$

$$S_1 = \sin \frac{2\pi}{t} \tag{2}$$

Initializing the following:

$U_2 = 0$ $\qquad$ $C_2 = 1$

$U_1 = 0$ $\qquad$ $S_2 = 0$

A recursive sequence is then used to compute U_o, U_1 and U_2:

$$U_o = Y_r + 2C_2U_1 - U_2 \tag{3}$$

$$U_2 = U_1$$

$$U_1 = U_o$$

for values of r = t-1, t-2, . . . , 1.

The coefficients are then:

$$a_j = \frac{2}{t} (Y_1 + C_2U_1 - U_2) \tag{4}$$

$$b_j = \frac{2}{t} (S_2U_1) \tag{5}$$

The values of C_2 and S_2 are updated to:

$$Q = C_1C_2 - S_1S_2$$

$$S_2 = C_1S_2 - S_1C_2$$

$$C_2 = Q$$

The sequence starting at equation (3) is repeated until j = 1, 2, . . . , m+1 pairs of coefficients have been calculated.

D.5 REGRESSION ANALYSIS (Ref. D-2)

The progression upward or downward of some dependant variable, Y, with respect to the change in some independant variable, X, can be characterized by the function:

$$Y = a + bX$$

where a = the value of Y when X = 0

and b = the slope of the trend line, $\frac{dy}{dx}$.

From a set of corresponding X and Y values, the constants a and b, the measures of dispersion about them, the significance of b differing from 0, and the correlation coefficient of Y on X can be calculated by least-squares methods:

$\Sigma x_i^2 = \Sigma X_i^2 - (\Sigma X_i)^2/n$ (the summation indicates $i = 1, \ldots, n$; n = sample size) (1)

$\Sigma y_i^2 = \Sigma Y_i^2 - (\Sigma Y_i)^2/n$ (2)

$\Sigma x_i y_i = \Sigma X_i Y_i - (\Sigma X_i)(\Sigma Y_i)/n$ (3)

$\bar{x} = \Sigma X_i/n$ (4)

$\bar{y} = \Sigma Y_i/n$ (5)

$b = \frac{\Sigma_{xy}}{\Sigma x^2}$ (subscripts are dropped for ease of printing) (6)

$a = \bar{y} - b\bar{x}$ (7)

$s_{y.x} = \frac{\Sigma y^2 - (\Sigma xy)(b)}{n - 2}$ standard error of the estimate (a) (8)

$s_b = s^2_{y.x}/\Sigma x^2$ standard deviation of the slope (9)

$t_b = b/s_b$ Student's "t" for the probability of b = 0, with n-2 degrees of freedom (10)

$r = \Sigma xy/ \quad \Sigma x^2 \Sigma y^2$ correlation coefficient (11)

r^2 = coefficient of determination

$(r^2)(100)$ = percent variation in Y associated with the variation in X

t_b also represents the significance of r with n-2 degrees of freedom

D.6 CALCULATION OF MEAN, STANDARD DEVIATION, AND 95% CONFIDENCE INTERVAL (Ref. D-2)

Let $X_1, \ldots, X_n$ represent the observations in a sample of size n ($i = 1, \ldots, n$).

$$\bar{x} = \sum_{i=1}^{n} X_i/n$$

The arithmetic mean of the sample

$$s = \frac{\sum_{i=1}^{n} X_i^2 - (\sum_{i=1}^{n} X_i)^2/n}{n - 1}$$

the sample standard deviation, a measure of dispersion of the observations about the mean of the sample

95% confidence interval = $\bar{x} \pm 1.96s$, the region about the mean within which approximately 95% of the sample values fall

D.7 REFERENCES

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APPENDIX E

OPTIMAL-ADAPTIVE PREDICTION

E.1 INTRODUCTION

During an ongoing air pollution episode, the objective of optimal-adaptive prediction is to provide the control district official with the ability to predict the effectiveness of the planned emergency actions and from this data, optimize the abatement tactics. The air pollution control district would use a prediction capability to provide them with enough flexibility to anticipate the severity of the episode, both with and without an abatement action. If the planned action does not appear to be effective, then the principal plan may be modified as the conditions dictate. For the prediction to be meaningful, the model describing the situation must be frequency calibrated to reflect the current situation and the immediate past history of the episode.

A model which can detect a systematic deviation of its computed results from the measured data and can correct itself to reduce the deviations is called an adaptive model. The elements of such an adaptive process include a model with emphasis on the effectiveness of the emergency action strategies (Section 3.4), accumulated monitoring data, both meteorological and air sampling (Section 3.3), a model identification process to adapt the model to reflect the currently measured situation (Appendix F), a computer simulation of the pollutant buildup during the episode and a display of the simulation data. To say that the process is an optimal-adaptive one refers to the technique used to update the model. An example of an optimizing model identification technique is given in Appendix B. The process optimizes the values of model parameters by minimizing the total variance of model data with measured data over a pre-selected time span (see Figure E-1) at intervals during the episode.

The purpose of this Appendix is to discuss the requirements and use of the adaptive process in episodes.

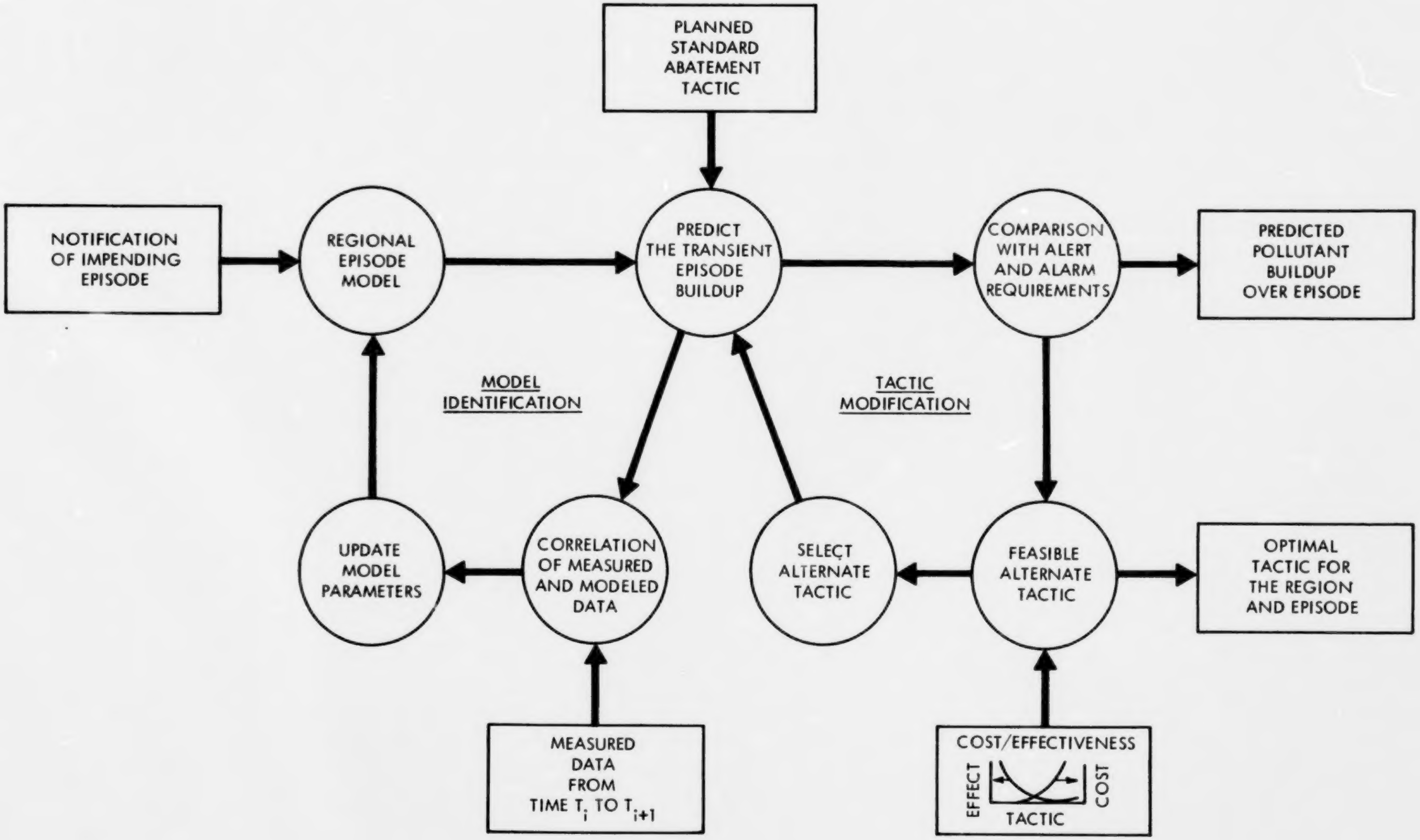
PLANNED STANDARD ABATEMENT TACTIC
NOTIFICATION OF IMPENDING EPISODE
REGIONAL EPISODE MODEL
PREDICT THE TRANSIENT EPISODE BUILDUP
COMPARISON WITH ALERT AND ALARM REQUIREMENTS
PREDICTED POLLUTANT BUILDUP OVER EPISODE
MODEL IDENTIFICATION
TACTIC MODIFICATION
UPDATE MODEL PARAMETERS
CORRELATION OF MEASURED AND MODELED DATA
SELECT ALTERNATE TACTIC
FEASIBLE ALTERNATE TACTIC
OPTIMAL TACTIC FOR THE REGION AND EPISODE
MEASURED DATA FROM TIME T_i TO T_{i+1}
COST/EFFECTIVENESS
EFFECT
COST
TACTIC

Figure E-1 Optimal Adaptive Prediction

E.2 REQUIREMENTS AND USE

The functions of an adaptive prediction process are to provide the control officer with both insight and flexibility. The insight is obtained through the ability to predict the effects of various abatement actions and the flexibility arises from the ability to choose the best from among several pre-planned actions and from the ability to make the choice based upon the actual present conditions.

The adaptive prediction of episode effects at intervals during an ongoing episode may not require the same depth and detail of modeling as does the planning process. The real time analysis will principally evaluate the deviations from actual conditions from those standard conditions which were assumed to exist during the planning studies. Based on the results of the planning studies, it may be possible to simplify the model. Suitable prediction accuracy is ensured by the updating of the model parameters at frequent intervals as the data permits. For real time use, the model will be capable of predicting both the expected and the worst case behavior of the episode based on measured current conditions.

Typical use of the adaptive prediction capability by the control district follows these procedures:

(a) The control district is notified by the weather service of the possibility of an impending episode.

(b) The regional model is updated to reflect the anticipated meteorological conditions and calibrated to current air pollution conditions using a model identification procedure similar to that of Appendix B.

(c) The severity of the uncontrolled episode is predicted and a preferred abatement strategy is selected from among the alternates.

(d) As data accumulates, the original meteorological forecast is continually checked against local monitoring data and revised forecasts. Also, the predicted air pollution concentration is compared against measurements from the air sampling stations.

(e) In the event of any significant deviation in either meteorology or pollutant concentrations, the model is updated and the episode behavior predicted again. At this point, it should be verified that the control action is still adequate and if not a better alternate selected.

It is necessary during an episode to have monitoring data automatically relayed to the central data bank of the control center. In addition, direct communication with the computer should be possible from the control center. This direct communication will allow rapid prediction and evaluation of several alternatives in the event that conditions rapidly change and require a re-assessment of the situation. There should be a continual and updated display of dose isopleths superimposed on regional maps in the control center displaying the current and predicted status. In addition to the isopleths display, time buildup transients of the concentrations and doses of the more important pollutants will be desirable, for both the expected and worst case conditions. Worst case includes the assumption of credible malfunctions in addition to unanticipated meteorological conditions.

The use of the adaptive process ensures that the models will be applicable to the current situation, and, in addition, provides a reasonable degree of confidence that the prediction of the effects will be realistic. The use of adaptive prediction will provide the control district with the flexibility to alter the abatement plan if the conditions are not as anticipated in the planning study.

APPENDIX F

MODEL IDENTIFICATION

F.1 INTRODUCTION

Model identification is a means of specifying a model of a situation to fit a particular condition of interest. The purpose of model identification is to verify the structure of the model by comparing the model's response to the measured response of the actual process. Model parameters are identified or varied to minimize the total error between modelled and measured data. The objective of this Appendix is to discuss a methodology of model identification with respect to its application in the planning and prediction phases of air pollution episodes.

Why is it necessary to incorporate model identification in the planning or prediction process? The principal reasons why each region is different are due to the distribution of pollutant sources, topography, characteristic meteorology, health sensitivity of the population, and air quantity objectives. The distribution of sources, their total emission rates, and the kinds of distributions of pollutants vary from region to region. The topography and meteorology of the region also vary widely. The health sensitivity of the population varies considerably between regions and with respect to their reactions to various mixtures of pollutants. Depending on the size of the populations and their sensitivity, the control district will have different objectives with respect to both air quantity and "reasonable cost" required to meet the objectives.

Model identification is used whenever it is mandatory to tailor the model to the particular region in question. It is expected that each region would require a model identification effort because of the expected dissimilarities. The process of model identification is required in both the planning and the prediction activities of the air pollution abatement tactics evaluation. In planning, its use is to study each region taking into account in the model the particular characteristics and problems of the region. In prediction, its use is to adapt the model to the actual conditions of the region in intervals as an episode unfolds, each time predicting the total affects of the episode. In both planning and prediction, its function is to support the evaluation of emergency actions. The submodels of the total regional model which are more affected by the identification techniques are:

(a) The dispersion model accounting for the source location and strengths including the transformation of the pollutants as they disperse over the region;

(b) The effect of control actions on the total regional source pollutant emission rate; and

(c) The economic model associated with the control action and the resulting change in emission rate.

Examples of adjustable dispersion model coefficients are wind velocity and direction parameters, inversion height parameters, characteristic pollutant distribution shape parameters, as influenced by diffusion coefficients, convection coefficients, and characteristic circulated patterns. The model of the situation must be tuned to calculate the pollutant concentrations within the desired precision and accuracy of the control district, as verified by measured data under near episode conditions. Similarly, economic models must be tuned to reflect the combination of all of the cost-estimating relationships supplied by the various industries for the alternate control actions under consideration. As a result of the model identification, the control district will be able to simulate the response of the total district emission rate for each constituent following the execution of an emergency action plan with a model which is specific to the control district and meteorological conditions. An example of the behavior of a modelled situation compared with the measured response of the actual situation demonstrates the need for model identification techniques (see Figure B-1). The comparison shows how the variation of a single model parameter can affect the total variances between modelled and measured response.

F.2 METHOD

What is the basic quantitative strategy of model identification for use in episode avoidance planning? The strategy is primarily based on adjusting identified parameters in the model to minimize the total area between two curves - a measured data curve and a modelled data curve.

Equations 1 and 2 show this strategy for one-variable and multi-variable measurements.

$$\min = \int_{t_o}^{t} (Y^*-Y)^2 dt \tag{1}$$

$$\min = \int_{t_o}^{t} (\bar{Y}^*-\bar{Y})^T \,\bar{\bar{W}}^{-1} (\bar{Y}^*-\bar{Y}) dt \tag{2}$$

where (T) represents the tranfer of a vector.

A single bar over a variable indicates that it is a vector, and a double bar indicates a matrix. Y is a measurable quantity which is computed from the model and Y* is the measurement. Equation 3 is an ideal functional relationship of the model to compute Y.

$$\bar{Y} = \bar{g}(\bar{X},t) \tag{3}$$

X is also computed from the model and is called the state of the system.

$$\bar{X} = \bar{F}(\bar{X}_o,t), \; \bar{X}_o = \bar{X}(t_o) \tag{4}$$

X is determined from a time-dependent model, e.g., integrated differential equation. The state variables of a system include those variables into which randomness or noise is introduced and also the model parameters which are to be identified. These are the unknowns of the process. Since the strategy involves the minimization of the area between modelled data and measured data, the model must reflect the sources of uncertainty as a result of noise in the measurements and noise in the model. The random effects in the model and the measurements are introduced as shown in Equations 5, 6, 7.

$$\bar{X}^* = \bar{X} + \bar{\varepsilon} \tag{5}$$

The modelled measureable variables, Y, should actually be computed based upon the "noisy" state variables, X*, rather than the noise-free state variables, X,

$$\bar{Y} = \bar{g}(\bar{X}^*,t) \tag{6}$$

and the relationship between modelled and measured data.

$$\bar{Y}^* = \bar{Y} + \bar{\eta} \tag{7}$$

Equation (6) should replace Equation (3) as the model for computing measured variables. Both noise-source terms are characterized by the covariance matrices shown in Equation (8).

$$
\begin{aligned}
E(\bar{\varepsilon}_i \bar{\varepsilon}_j^T) &= \begin{cases} 0 & i \neq j \\ \bar{\bar{R}}_i & i = j \end{cases} \\
E(\bar{\varepsilon}_i \bar{\eta}_j) &= 0 \qquad\qquad \text{i and j are points in time} \qquad (8) \\
E(\bar{\eta}_i \bar{\eta}_j^T) &= \begin{cases} 0 & i \neq j \\ \bar{\bar{W}}_i & i = j \end{cases}
\end{aligned}
$$

T indicates the transpose of a vector.

The noise sources are assumed to be uncorrelated in time, i to j.

The strategy in model identification can now be more precisely stated in several parts:

(a) The desire to minimize the covariance weighted deviations of the values of the initial state vector.

$$\text{min1} = (\bar{X}_o^* - \bar{X}_o)^T \bar{R}_o^{1} (\bar{X}_o^* - \bar{X}_o) \qquad (9)$$

(b) The desire to minimize the covariances weighted measurement data differences at each time point over the episode time span of interest.

$$\text{min2} = [\bar{Y}^* - \bar{Y}]^T \bar{\bar{W}}^{-1} [\bar{Y}^* - \bar{Y}] \qquad (10)$$

(c) The desire to minimize the covariance weighted state noise deviations over the episode time span of interest.

$$\text{min3} = (\bar{X}^* - \bar{X})^T \bar{\bar{R}}^{-1} (\bar{X}^* - \bar{X}) \qquad (11)$$

(d) The total quantity to be minimized is the combination of all three of these objectives.

$$\text{min} = \text{min1} + \text{min2} + \text{min3} \qquad (12)$$

The minimization of the total error as expressed by Equation (12) is performed with respect to adjustments in initial values of the state variable and with respect to adjustments in the assumed noise of the state variables with the objective of driving the state noise term to zero if possible. TRW has developed and used for a period of several years, methods of solving for the optimal values of both the initial values of the state variable and the state error terms, $\bar{X}_o$ and $\bar{\varepsilon}$.

Since the model parameters to be varied are a part of the state vector, these methods provide the capability to find an additional quantity of interest besides model parameters. This quantity is the initial value of state variables which are not measureable and are not known precisely, based on other measurements on the process. The techniques which have been developed are all based on linearization, utilizing analytical partial derivatives which are internally derived by special software operating on the process model. The use of analytical partial derivatives results in impressive convergence properties of the method. The method of optimization is based on linearization, e.g., for the measurable variables

$$\bar{Y} = g(\bar{X}^*, ot) \quad \bar{g}(\bar{X}+\bar{\varepsilon}) + \bar{\bar{M}}' \, \delta\bar{\varepsilon} + \bar{\bar{M}}'\bar{\bar{\phi}} \, \delta\bar{X}_o \qquad (13)$$

where

$$\bar{M}' = \frac{\partial \bar{g}}{\partial \bar{X}^*}$$

$$\bar{\bar{\phi}} = \frac{\partial \bar{X}^*}{\partial \bar{X}_o}$$

$$\delta\bar{X}_o = \bar{X}_o^{n+1} - \bar{X}_o^{n}$$

$$\delta\bar{\varepsilon} = \bar{\varepsilon}^{n+1} - \bar{\varepsilon}^{n}$$

but ε is desired to be zero: $\bar{\varepsilon}^{n+1} = 0$.

$$\delta\bar{\varepsilon} = -\bar{\varepsilon}^{n}$$

n refers to the n^{th} iteration of the updating process.

The linearization as shown provides the mechanism for computing the variables of interest, X_o and ε which best match the measured data.

Convergence is achieved when the change of the total payoff function, d(MIN), is within the convergence tolerances with respect to changes in $\bar{X}_o$, $\delta\bar{X}_o$, and $\bar{\varepsilon}$, $\delta\bar{\varepsilon}$.

The model identification procedure is based on onlinear system models and linear noise models. The linear noise model assumption is valid so long as the amplitude of the noise is small compared to the mean values of the state variables and the measured variables. The error terms allow the model parameters to vary in order to fit an assumed "noisy" model data curve to a "noisy" measured data curve with minimum total error. This technique has been used successfully in many of TRW's projects demonstrating its economical usefulness based on a highly convergent analytical technique. The minimum variance model identification procedure is a part of the same package of proprietary system optimization programs as the generalized optimization procedure which was discussed in Appendix A.

APPENDIX G

REMOTE SENSOR DESCRIPTION

G.1 TEMPERATURE

G.1.1 RADIOMETER SENSOR

Every object in nature radiates electromagnetic energy of all wavelengths from the ultraviolet, through the infrared to the microwave part of the spectrum. The intensity of the radiated energy in any part of the spectrum depends upon the temperature of the object. The average temperature of the atmosphere is such that the radiated energy is most intense at infrared wavelengths between 1 and 1000 microns, peaking at 9 microns. By measuring the intensity of the radiation in the infrared portion of the spectrum with an infrared radiometer or in the microwave portion of the spectrum with a microwave radiometer one can calculate the temperature of the portion of the atmosphere that is being observed (Ref. G-1).

The measurement technique depends on the fact that certain atmospheric gases strongly absorb certain wavelengths of sunlight as they pass down through the atmosphere. For example, carbon dioxide strongly absorbs infrared radiation, while oxygen strongly absorbs microwave radiation. Gases that absorb strongly also radiate strongly, and the intensity of the reradiated solar energy is a measure of the temperature of the gas. The measurement technique further depends on the fact that the gases absorb only a small portion of the wavelengths in any one part of the spectrum and transmit the rest. The portion absorbed is called an absorption band and the portion transmitted is called a transmission window.

A microwave radiometer senses the natural radiation reradiated from oxygen molecules in the atmosphere. The measured amount of radiation is proportional to the temperature of the oxygen molecules that make up a major part of the atmosphere and, consequently, of the atmosphere itself. For this technique to be successful it is necessary that the atmospheric gas have a constant distribution throughout the atmosphere and that its absorption-reradiation characteristics vary significantly with wavelength. Oxygen has strong absorption-emission bands in the microwave region (5 millimeter wavelength) and is a suitable gas for the purpose.

An important characteristic of oxygen is the change in its absorption characteristics with wavelength and pressure and the lack of change with temperature. Since the absorption coefficient increases with pressure, absorption of radiation at a given wavelength is greater at ground level than it is at higher levels. Therefore, one can tune the radiometer to sense a range of wavelengths from those just inside the transmission window to those just inside the absorption band that peaks at 5 millimeters wavelength, and compute the vertical temperature profile by a mathematical technique called inversion.

Another way to determine the atmospheric temperature profile is to hold the wavelength constant and vary the elevation angle of the radiometer. This assumes a stratified atmosphere within the line of sight of the radiometer antenna, which is a reasonable assumption for the low altitudes pertinent to air pollution. Information from greater heights in the atmosphere can be obtained by using slightly longer (about 2%) wavelengths.

The physical nature of radiation coming from many levels, regardless of the elevation angle, is such that radiometeric probing methods smooth-out temperature discontinuities, such as temperature inversions. The importance of this effect will depend upon the height and magnitude of the inversion. In general, the lowest and strongest inversions are measured in the greatest detail.

Temperature profiles in the first mile of the atmosphere can be specified remotely with accuracies approaching those obtained with a radiosonde, i.e., 0.7°C RMS (Ref. G-2). In fact, during comparative field tests using a radiometer, an instrumented 1500-foot television tower and a radiosonde, it was not unusual to have the microwave radiometer measurements match the temperature structure observed by the sensors mounted on the tower in much more exact detail than did the radiosonde.

The second radiometric method measures atmospheric temperature by sensing the infrared radiation coming from the carbon dioxide molecules in the atmosphere. A commercial version of this type of radiometer is the Barnes Engineering Company Opti-therm.

Measurements of the temperature profile of the atmosphere are made by tuning the radiometer over a continuous range of wavelengths near the edge of the atmospheric window. One tuning range that has been used extends from 13 microns to 14 microns, where absorption by the carbon dioxide in the atmosphere begins to be significant. Atmospheric absorption varies with wavelength over the tuning range, being lower at the window side at 13 microns and greater at the absorption band side at 14 microns wavelength. Radiation received by the measuring instrument during the tuning cycle includes samples arriving from progressively higher layers of the atmosphere, so the measurements can be inverted into an altitude profile of the temperature within the mixing layer.

The change of wavelength is obtained in a device currently under test aboard an airplane by a rocking etalon assembly of a Fabry-Perot spectrometer. A newer design with a different mechanism for scanning over the wavelength region is in the early stages of development. It will use a rotating variable-wavelength interference filter, and should result in a smaller and lighter package.

No data on accuracy are available because no tests of a ground unit have been run. Actually, the nature of the absorption-reradiation process is such that the infrared technique is better suited to being carried in an airplane and looking down from above. The microwave radiometer sensor has been field tested and is deemed by the Sperry Microwave Electronics Company, Clearwater, Florida, the developer, to be ready for operational use. There is a 7 to 9 month delivery schedule.

G.1.2 WIRESONDE

The wiresonde is a temperature and dew point measuring device that is carried aloft on a captive balloon called a kytoon (Ref. G-3, p. 1216). It has been used extensively in atmospheric reasearch and is the most accurate and reliable method to measure temperature at a remote point.

The wiresonde unit consists of the sensing elements, radiation shields, blower, and batteries; the entire unit weighing approximately 3/4 lb. Temperatures are measured by means of a tiny ceramic bead, similar to that employed in the standard radiosondes. For dew point a thermistor bead identical to that used for temperature measurements is covered with a light cloth wick immersed in a reservoir of water. For dew point temperatures below freezing, the lithium chloride electrolytic element is used.

Proper ventilation for these elements is supplied by a small blower, powered by a six-volt cuprous chloride-magnesium water-activated battery.

The data recording device is located on the ground and consists essentially of a Wheatstone bridge with the balancing dials calibrated to read either the temperature directly or, by throwing a switch, the dew point temperature or relative humidity. The resistance network of the bridge is compensated for the resistance of the cable leads. In operation, the bridge is electrically connected to the thermistor beads through a nylon-encased three-conductor cable, 2000 ft. long and weighing about 4.5 lb that is attached to the kytoon tether.

To maintain the wiresonde at a reasonably constant height during observations, a kite-type balloon called the "kytoon" is used. The kytoon is streamlined and combines the aerodynamic properties of a balloon and a kite. The balloon is approximately 6-1/2 ft long and 39 in. in diameter. During a strong wind, the kytoon lifts like a kite rather than being blown downwind as with a captive spherical balloon. Under average conditions the kytoon has a lift of about three pounds. Calculation of the height of the sensing elements is made by measuring the length of cable payed out and the angle of the cable leaving the reel. Difficulties in computation arise if a variable wind is present.

With the proper exposure and ventilation of the sensing elements, temperature may be measured with a root-mean-square error of about ±0.1°C over the temperature range of from +40°C to -40°C. The dew point reading can be made with a probable error of ±0.2°C for temperatures above 0°C. The lithium chloride strip will yield values of relative humidity to within ±2 per cent for temperatures to -10°C and for humidity ranges of 15-96 per cent.

A temperature profile can be obtained by taking readings as the kytoon rises and as it is reeled in. Alternatively, wiresondes can be attached to the tether at regular intervals. A disadvantage of the wiresonde technique is that the kytoon and tether are a hazard to low flying airplanes and the FAA has required that marker flags be attached to the tether at 50 foot intervals.

The retail cost of a bead thermistor sensor is about $3 and the cost of the wiresonde about $15 plus about $2 for batteries. If a precisely calibrated bead is used, the bead cost alone is $30.

G.1.3 RADIOSONDE

The most widely used sonde is the radiosonde launched routinely by the Weather Bureau (Ref. G-3, p 1207). It consists of a helium filled balloon that lifts a small radio transmitter and temperature, pressure and humidity sensors to well over 50,000 feet. Measurement accuracies experienced by radiosonde users at the National Missile Ranges are tabulated below. (Ref. G-2.)

Property	RMS Accuracy
Pressure	0.7 mb
Temperature	0.7°C
Relative Humidity	5%
Wind Speed	3 knots
Wind Direction	5°
Cost	
600 gm balloon and parachute	$4.20
Radiosonde and battery	$23.00
Helium	$8.60
Miscellaneous Expense (Personal)	$19.00
GMD-4 radar, recorder, etc.	$55,000

A radiosonde that measures wind is called a rawinsonde and the costs cited are for this unit (see G-2.2 Rawinsonde).

The needs of episode forecasting could be met very well by radiosonde alone, but they are cumbersome to launch and monitor. Providing a sufficiently dense network of radiosondes specifically for episode planning probably would be too complex and expensive. Every effort should be made to secure the data from the routine Weather Bureau and military service radiosonde runs. Also, arrangements should be made for extra soundings as often as possible when an episode condition is forecast.

G.1.4 ROCKETSONDE

A rocketsonde is a rocket that carries a radiosonde to the proper altitude, ejects it on a parachute and measurements are made on the way down. The recent development of small rockets that use compressed gas or steam, rather than rocket fuel, make this technique practical for use in urban areas. One of these is the Cricket rocketsonde developed for the Air Force and Navy by Texaco, Inc (Ref. G-4). Compressed carbon dioxide propels the rocket to 3,000 feet where a parachute is deployed and the rocket is returned to earth by a 5-foot diameter parachute. A steam fueled rocket has been designed by Experiment, Inc., but it is not available for field use. The rocket is reusable; in fact, it is economical only if it is recovered and reused.

The decending rocketsonde transmits a record of pressure, temperature and humidity of the atmosphere through which it passes. A multivibrator is used to switch temperature and humidity sensors into the circuit. The baroswitch over-rides the multivibrator to give pressure readings. The transmitter is designed to operate in the 403 Mc meteorological band. The entire payload including battery weighs 3/4 pound, and the total weight of the fueled rocket is 5-1/2 pounds.

The temperature and humidity sensors are mounted in a vented housing and are exposed to the atmosphere by attachment to the parachute lanyard. A sample of data is obtained every 30 feet on descent. During flight, pressure points are obtained for each 500 feet of altitude. The ground receiving system consists of a manually operated antenna, receiver, recorder and power generator.

Telemetering lasts for approximately six minutes, as the parachute descends at a rate of about 500 ft./min. The temperature and humidity data were reduced in a manner similar to that employed in standard radiosonde operations, utilizing special charts prepared by Bendix-Friez. Pressure values are obtained using a ten point calibration chart. The pressure points over-ride the temperature and humidity measurements and occur approximately every five seconds (500 feet of altitude).

Currently the Cricketsondes cost about $200 but it is expected that the cost will drop to about $80 in quantity procurement. This breaks down to about $35 for the vehicle and $45 for the payload. If each unit were to be used ten times, the cost per shot would be in the order of $8. Experience has shown that reusable Crickets require a new battery and occasionally a new temperature or humidity element, thus a unit cost figure of $10 is more realistic. The fuel required for each Cricket launch is very nominal in cost, under $.50.

Some problem areas are inherent in the current Cricketsonde system, although none appear to be insoluble. An operational system, for example, should transmit on 1680 Mc and have a capability for automatic wind sensing through the use of a transponder or other technique.

G.1.5 LASER/SPECTROMETER

It has been suggested that a spectrometer using a laser as an illumination source can be used to measure the density, temperature and, ultimately, the pressure of the atmosphere (Ref. G-5). The method has received much attention, but it has not progressed past the study phase. As laser technology advances this technique could become the principal method of measuring atmospheric properties remotely, particularly over a long path where the laser light is reflected back to the spectrometer by a mirror mounted on a distant smoke stack or television tower.

The pressure and temperature of the atmosphere over a particular long-path or at a particular altitude can be determined if the shape of an absorption line of one of the atmospheric gases could be accurately measured. This is true because the two phenomena which govern breadth or shape of atmospheric absorption lines are pressure broadening due to molecular collisions and Doppler broadening due to thermal molecular velocities.

Pressure affects the shape of spectral lines by increasing the uncertainty in both energy levels involved in the transition. It does this by decreasing the lifetimes of each state through molecular collisions. Since each molecular collision can change the state of a molecule, the lifetime of a state is decreased due to the increased collision frequency at the higher pressures, and the spectral lines are consequently broadened. The shape of a pressure-broadened line is normally given by the Lorentz line-shape function, and the half-width at half maximum intensity is related to the temperature.

The actual measurement of the shapes of atmospheric absorption lines using the laser absorption and scattering techniques is a painstaking task. The full absorption line widths are only about 200mÅ wide at atmospheric pressure, so very careful control of the frequency and intensity of several laser beams ranging in wavelengths across the absorption line is necessary.

G.2 WIND

G.2.1 PILOT BALLOON

Wind in the upper atmosphere routinely is measured by tracking a free balloon, called a pilot balloon, with a theodolite (Ref. G-3, p 1214). As the pilot balloon rises it moves with the wind and the altitude and direction angles are measured every 30 seconds or so by the elevation and azimuth scales on the theodolite. Since the pibal rises at a known rate, the wind speed and direction at each altitude can be computed by trigonometry.

This technique has been used by the Weather Bureau for decades and is thoroughly proved out. The theodolite is an optical telescope and requires only the care normally afforded a quality optical device. The balloons are filled directly from helium cylinders. A plotting board is used to compute wind speed and direction and some training is required to perform this computation.

Accuracy	±1 kn (vector)
Maintenance	nil
Cost 100gm balloon	$0.35
helium	$1.50

G.2.2 RAWINSONDE

Wind also can be measured by tracking the balloon borne radiosonde by radar as it rises (Ref. G-3, p 1207). This version of the GMD-1 radiosonde system is called a rawinsonde and designated a GMD-2 or GMD-4. A radar set is required as well as a computer to calculate the wind speed direction and altitude. The rawinsonde is an ideal way to determine winds, since it is less sensitive to weather than the purely visual pilot balloon method and is largely automatic. However, the equipment is expensive and only major Weather Bureau stations will have it. Arrangements should be made with the local Weather Bureau to have special soundings run and the wind data forwarded immediately when an episode is imminent.

Property	Accuracy
Wind Speed	3 knots
Wind Direction	5°
Cost	
Expendables	$55
Radar, recorder, etc.	$55,000

G.2.3 RADIOMETER

A technique that uses two ground-based radiometers to measure the upper wind is under field test by NASA Marshall Space Flight Test Center (Ref. G-6). It is called crossed-beam monitoring and measures the wind by the statistical cross correlation of the radiation received from the atmosphere (Ref. G-6). The basis of the technique is that the wind carries with it the natural dust and other particles of the atmosphere. These aerosols affect the intensity of skylight that is reflected downward by the atmospheric gases and aerosols through the processes of scattering, absorption and radiation. The intensity of the skylight from a given volume of atmosphere varies as the wind carries lesser or greater concentration of aerosol through the volume and, by monitoring the variation in intensity of skylight, one can determine the wind velocity using statistical mathematics called cross correlation.

Two monochromator radiometers are positioned some distance apart and looking upward at the level in the atmosphere where the wind measurement is to be made. Each monochromator monitors the time variation of the skylight in the volume of atmosphere within its own field of view. The fluctuations of each signal then are combined in a cross correlation analysis to determine the wind speed at the point where the two fields of view nearly intersect. The method has successfully measured the flow in a jet exhaust to an accuracy of 10% and plans are underway to test it in the actual atmosphere.

The monochromators are sensitive to a wavelength that is partially absorbed or reflected away by the aerosols that are in the atmosphere.

Thus, wind-induced fluctuations of the concentration of the aerosol appear as fluctuations in the reading of the radiometers. Each radiometer alone, of course, senses only the sum of the aerosol fluctuations along its entire line of sight. However, the developers of the method have shown that subtraction of the two radiometer readings eliminates much of this sum, yielding information just on the local wind in the volume where the lines-of-sight nearly intersect.

The local wind is obtained as follows: the intensity of the skylight sensed at any instant by a radiometer represents the sum of the wind all along its line of sight. This wind effect consists of two parts. First, the wind fluctuations which occurred sufficiently close to the line of sight intersections to have an effect in both radiometers. The second fluctuations occur far enough distant from this point that their effects on the radiometer readings are random and are sensed by only one or the other radiometer. If the time-averaged product (covariance) of the readings of the two radiometers is computed, those portions of the reading created by the second wind effect will average out to zero. The first wind effect will have a finite average product that is not zero and that is indicative of the wind in the volume where the lines-of-sight nearly intersect.

G.2.4 LIDAR

It has been proposed that wind velocity might be measured by laser radar (lidar) techniques utilizing reflections from windborne aerosols (Ref. G-7, G-8). The light reflected from a single aerosol particle is simply a delayed (and attenuated) replica of the transmission. This delay is interpretable as a phase difference. If the aerosols are moving, then the signal return exhibits a continuously changing phase. For a constant velocity target, the return signal phase will vary at a constant rate, thus giving rise to a Doppler frequency shift. The Doppler technique has been used successfully in Doppler navigation systems and for Doppler measurements of the speed of falling rain drops.

The use of lidar techniques for wind velocity measuring is under study by NASA Electronics Research Center and the aerospace industry (Ref. G-9). Although the technique shows great promise, it still is in the laboratory experiment stage and is not expected to be available to the episode planning program until the middle 1970's.

G.2.5 RADAR/ACOUSTIC

Measurement of wind by monitoring the reflection of radar waves from an artificial sound pulse has been proposed. The Electromagnetic-Acoustic (EMAC) probe proposed by Midwest Research Institute consists of a high-intensity directional acoustic source and a Doppler radar system.

The probe operation is based on the fact that the periodic pressure variations in an acoustic wave are also periodic variations in the dielectric constant of the medium and will therefore reflect a portion of an incident electromagnetic wave such as that from a radar. Since the acoustic wave is propagating in the atmosphere, it will have a total velocity which is the vector sum of the local sound velocity and the wind velocity. The reflected electromagnetic energy will therefore be received with a Doppler frequency shift which is exactly proportional to the total velocity of the acoustic wave as seen by the radar. This Doppler frequency shift may then be used to accurately determine the velocity of the acoustic wave and, if the velocity of sound can be determined and subtracted, will provide the velocity component of the wind in the direction of propagation. The local sound velocity may be determined approximately from temperature measurements or more accurately by additional velocity measurements in different directions. This technique has not progressed past the design stage.

Early concepts of the EMAC system tried to keep the radar pulse in coherence with the acoustic pulse. But in 1963 researchers rejected this because turbulent inhomogeneities necessitate costly and complex electronic circuitry.

They believed that it would be feasible to create a moderate burst of sound waves whose wave fronts would steepen to become shock waves within a few hundred feet of the source. These waves would remain shock waves for a distance of about 10,000 feet. This would reduce the damage to personnel near the sound source. The following is a list of suggested sources of the sound waves.

(1) Yachting cannon
(2) Dynamite
(3) Mild explosives
(4) Internal combustion devices
(5) Compressed air discharge

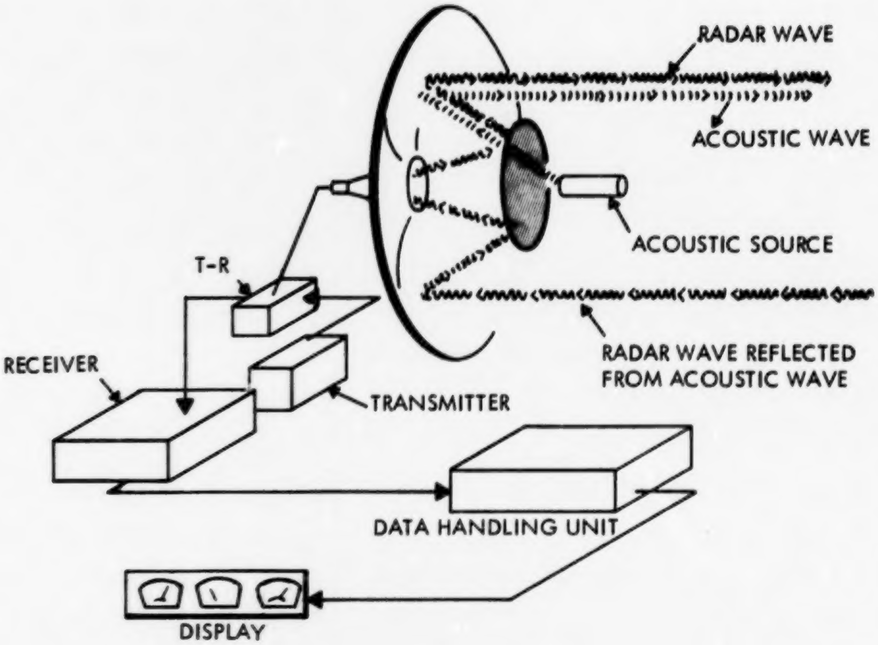
RADAR WAVE
ACOUSTIC WAVE
ACOUSTIC SOURCE
T-R
RECEIVER
RADAR WAVE REFLECTED FROM ACOUSTIC WAVE
TRANSMITTER
DATA HANDLING UNIT
DISPLAY

Figure G-1. EMAC Probe System

Another attractive proposal is to use Doppler radar and the natural aerosol of the atmosphere to measure wind. Radar reflective particles blowing across a radar beam of width $2\theta_o$, with a speed, W, will return signals to the radar having a spectrum of frequencies. The total variance of these frequencies is $\sigma^2 = \sigma_o^2 + \sigma_1^2$, where σ_o^2 is the variance of the uncontaminated spectrum and is related to wind and beam width in this way:

$$\sigma_o = 0.6\ \theta_o\ W$$

If this were the only term, measuring the transverse wind speed, W, would be a simple matter. However, the Doppler spectrum is broadened by contaminating factors such as turbulence, the spectrum of the fall speeds of the particles, and wind shear.

By using a third axial beam to measure σ^2 independently and subtracting out $2\sigma^2$ one can obtain a variance which is independent of both the contamination spectra and the beam width. The accuracy is then a function of the range, beam angle 2δ, and transverse wind speed. Furthermore, if the dual beam technique is combined with a Doppler system, the complete horizontal wind vector (radial and transverse components) can be determined.

G.3 WATER CONTENT

Two methods are available to measure the water content of the atmosphere in terms of relative humidity or dew point. Both of these are balloon borne devices that have been used routinely for decades by the Weather Bureau. The laser technique is still in the preliminary field test stage.

G.3.1 RADIOSONDE

The radiosonde discussed under Temperature also carries an electric hygrometer consisting of a carbon strip that measures the relative humidity to a root mean square accuracy of 5% when the temperature is above freezing and of 10% down to a temperature of -40°C (-40°F) (Ref. G-3).

G.3.2 WIRESONDE

The wiresonde discussed under Temperature also carries a thermistor and water reservoir that measures the dew point. The AN/UMQ 4 wiresonde with an aspirated wet bead thermistor used by NASA has an RMS accuracy of 3% for temperatures above freezing. For temperatures below freezing the accuracy is reported as questionable. The version using the lithium chloride strip has an RMS accuracy of 10% above freezing and questionable accuracy below freezing (Ref. G-3).

G.3.3 LASER/SPECTROMETER

With this technique the laser transmits a light pulse up through the atmosphere. Molecular and particulate backscattered light from the traveling pulse is received by a spectrometer on the ground and recorded as a function of time. The amount of light backscattered depends largely on the concentration of aerosols and other particles. (Ref. G-5, G-7, G-8, and G-9.)

Since the laser light pulse is monochromatic, if it is tuned to a particular chemical species, such as nitric oxide or water vapor, the light backscattered from the traveling pulse and received at the ground will be subjected to increasing absorption as it returns from greater heights. This absorption can be used in a quantitative determination of the amount of water vapor present, for example, if the intensity of backscattered radiation in the water vapor band can be compared with the intensity of backscattering in a spectral region that is outside a water vapor absorption band. The ratio of backscattered intensity in the band to that outside the band can be interpreted in terms of the height profile of water vapor density.

Experiments using a ruby laser tuned in the vicinity of the 6943 Å water vapor absorption bands have been underway for several years at New York University under the direction of R. M. Schotland. This work has been sponsored by the U. S. Army Electronics Command. Although the general conclusion of this work is that a thermally tuned laser radar can be used to determine in a qualitative sense the vertical profile of water vapor, the present long scanning time is unusable whenever the atmospheric aerosol content is variable. This limits operation to nighttime and strongly stable conditions. Quantitative measurements of the water vapor profile must await accurate data on the structure of the water vapor lines themselves, measurement of the spectral bandwidth of the laser pulse as a function of temperature, and better data on the relation between water vapor density and absorption.

The present system provides usable information to a height of 4 kilometers independent of the time of day. However, the operation of the system is restricted to nearly cloud free portions of the sky or the subcloud region.

G.4 PRESSURE

Only one remote pressure measuring method is readily available - the radiosonde. A pressure sensor has been test flown on the Cricket rocketsonde, but not in large enough quantities to deem it a field-ready device. The radiometer method is in the developmental stage.

G.4.1 RADIOSONDE

The radiosonde unit discussed under Temperature also contains an aneroid barometer that measures the atmospheric pressure during ascent. NASA experience with the unit is that rms accuracy is 0.7 millibars.

G.4.2 ROCKETSONDE

The Cricketsonde meteorological rocket discussed under Temperature carries a pressure-sensitive switch by means of which the atmospheric pressure profile during descent can be calculated. There is not sufficient field experience with the unit to cite its accuracy.

G.4.3 RADIOMETER

By adding a data processing unit to the microwave radiometer unit proposed for temperature measurement, it is possible to measure the pressure as well as the temperature.

G.5 GASEOUS POLLUTANTS

Considerable work has been done on the remote measurement of gaseous pollutants and correlation spectrometers exist as field ready instruments. The absorption spectrometer still is in the field test stage.

G.5.1 CORRELATION SPECTROMETER

Two parallel developments of correlation spectrometers have been completed to measure gaseous pollutants. One is an airplane borne device, and it has had several successful flight tests measuring the sulphur dioxide content of the underlying atmosphere (Ref. G-10). The other, that is designed particularly for ready shifting from one gaseous pollutant to another, is ground based and deemed to be ready for field use. (Ref. G-13).

The operation of the airborne spectrometer will be described, and the operation of the ground based version is similar. The existing airborne version measures the average amount of sulphur dioxide (SO_2) in the field of view of the instrument between the carrier airplane and the surface. Sunlight reflected from the atmosphere as skylight is the source of illumination. The reduction in intensity of the reflected skylight is a measure of the total amount of SO_2 in the atmosphere below the airplane.

Reflected skylight enters the spectrometer, all but the small portion of ultra-violet wavelengths between 2900 and 3150Å is eliminated, and the balance passed through a partly transparent-partly opaque correlation mask. The intensity of the portion passing the mask is a measure of the amount of sulphur dioxide in the field of view.

The actual quantity of SO_2 in parts per million per meter of path length is determined by calibrating the spectrometer with transparent glass cells that contain known concentrations of SO_2 in parts per million per meter of cell length. Dividing the concentration in ppm-m by the airplane altitude in meters, and correcting for the atmosphere pressure and temperature yields the sulphur dioxide concentration in parts per million. This is the average concentration in the column of atmosphere between the airplane and the ground and contained within the field of view of the spectrometer.

Gases other than SO_2 are excluded from the measurement by the placement of the transparent portions in the correlation mask. The narrow slits are placed 22Å apart to correspond with the fine absorption line structure that occurs at 22Å intervals across the major absorption band between 2900 and 3150Å. While other gases with similar absorption spectra might have fine structure absorption lines that match one or two of the slits in the mask, none will correlate with all nine slits at once. No gas but SO_2 has many fine structure absorption lines spaced exactly 22Å apart between 2900 and 3150Å.

The same technique is proposed to measure nitric oxide, ozone, and other pollutants. Different portions of the skylight would be admitted into the spectrometer and correlation masks matched to the absorption characteristics of the particular gas. The ground based version developed at the University of Florida is specifically configured for readily shifting from one gas to another.

The airborne version can measure the sulphur dioxide up to any altitude by flying the airplane at the top of the level desired. The ground based version measures all of the pollutant between the ground and the top of the atmosphere.

G.5.2 ABSORPTION SPECTROMETER

The differential absorption technique used to measure the temperature of the atmosphere also can be used to measure the amount of a pollutant like ozone. Rather than simultaneously measuring the radiation over a broad band of wavelengths, as does the correlation spectrometer, the absorption spectrometer measures the radiation of a few very narrow bands.

In the case of ozone the method takes advantage of the fact that the absorption of ultraviolet radiation by ozone is strongly wavelength dependent. This characteristic of ozone is such that the radiation backscattered or diffusely reflected during a smog situation does not come from the entire atmosphere, but is largely confined to a relatively thin mixing layer. The important factors in the measurement are the wavelength of radiation, zenith angle of the sun, the nadir angle of the direction of observation and the vertical distribution and the total amount of ozone within the mixing layer. Since the wavelength, sun angle, and observation angle are known, then measurements of the intensity of the backscattered radiation as a function of wavelength can be used to obtain information about ozone.

In 1963 personnel at the National Center for Atmospheric Research began work on the development of an ultraviolet double monochromator to determine the vertical distribution of atmospheric ozone from measurements of scattered skylight at several wavelengths (Ref. G-12). Mechanical design and fabrication of the monochromator is complete and integrated tests of the electronic control and electromechanical subassemblies is underway.

Another development in the field of optical techniques for the measurement of total ozone in the atmosphere was proposed by K. Murai of the Institute of Meteorological Research, Tokyo. He uses an interference filter apparatus on the principle of the Vassy spectrophotometer to obtain observations of total ozone thickness. Murai modified the Vassy instrument and included interference filters to reduce the influence of sky conditions on the observations. Transmission bands were made very narrow in order to separate completely the necessary wavelengths. Murai studied the results obtained and found that the observations were affected by the time of day, or the angle of the sun in the sky, as well as by cloud conditions -- cumulus more than cirrus clouds. He found that smoke, or dust, and haze were less important in influencing the observations. The error of measurement he concluded was more important the lower the sun was in the sky so that observations at sunrise and sunset were difficult to make. He made no effort to obtain the vertical profile of ozone by this means.

G.5.3 LASER/SPECTROMETER

The principal of operation of a laser/spectrometer is similar to that of the radiometer sensors discussed in section G.1.1. Instead of relying on reflected sunlight for illumination the laser/spectrometer uses laser light for illumination. They can operate at night when there is no sunlight. This sensor is particularly attractive for long-path sensing of pollutants where the laser light is reflected back to the adjacent spectrometer by a mirror mounted on a distant smoke stack or television tower.

To measure the amount of pollutant in the path the output of the laser must be two wavelengths, one of which falls on an absorption band of the pollutant being measured and one which falls near the absorption band, but not within it. The reflected intensity of the second wavelength will then serve as a control or reference against which the absorption of the first wavelength can be measured.

Many different lasers have outputs that meet these requirements. These include neon, argon, krypton, iodine, CO_2, CO, NO, N_2O lasers, and many others.

The two infrared lasers which appear to be the most useful for pollutant detection are the carbon dioxide (CO_2) laser and the iodine (I_2)

laser. Each of these emits lines which fall within the absorption bands of principal atmospheric pollutants, and each can be operated continuously with a good power output.

The CO_2 laser normally emits a wavelength of 10.6-micron, but by introducing an absorbing gas within the laser cavity itself the laser can be made to emit laser radiation at many other wavelengths.

The iodine infrared laser emits more power than most other known atomic laser systems; and second, it emits wavelengths which fall on the infrared absorption bands of three principal atmospheric pollutants: hydrocarbons, carbon monoxide, and nitric oxide. Ethylene, a prominent constituent of auto exhaust, is detected by slightly shifting the normal CO_2 laser emission by means of a small amount of propylene placed in the laser wavelength control compartment. The resulting line falls near the strongest absorption peak in the ethylene spectrum. For the detection of ozone in photochemical "smog" the emission is transferred to about 9.5 microns by the use of a slightly greater amount of propylene. A reference line against which ozone can be measured is obtained by use of still more propylene. Sulfur dioxide is detected by means of the oxygen-18 CO_2 laser. For the detection of carbon monoxide the 4.8-micron line of the iodine laser is used, the 5.5-micron line being suppressed by placing nitric oxide gas in the absorption cell of the laser. For the detection of nitric oxide, the 5.5-micron line of the laser is used, with the 4.8 line being suppressed by nickel carbonyl gas.

Water vapor can be measured with a ruby laser operating near liquid nitrogen temperatures, -196°C. There is a relatively strong and isolated H_2O absorption line at 6933.8Å, and this is the normal operating wavelength of the ruby laser when cooled to -196°C. If 0.085Å is taken as the linear coefficient of the rate of change of the ruby emission wavelength with temperature, then a second ruby laser operating near -183°C (the boiling point of liquid O_2) would have an output wavelength of 6935Å (Ref. G-13). The latter wavelength is in an atmospheric "window" where there is relatively little absorption. Therefore, with one ruby laser operating at the boiling point of liquid oxygen and a second operating at the boiling point of liquid nitrogen, there would be a pair of laser beams which could serve for the measurement of the number density (or composition) of H_2O molecules as a function of altitude in the atmosphere.

The laser/spectrometer shows great promise for gaseous pollution detection, but it exists at present only as a laboratory device. It is expected that by the middle 1970's field instruments will be available.

G.6 AEROSOL POLLUTANTS

The measurement of the altitude of aerosols by the reflection of laser light from them has been underway for 5 years by the Stanford Research Institute (Ref. G-7, G-8, G-9). They call their device a lidar. However, the problem of determining the size and composition of the aerosols has not yet been solved for field use.

Initially, the laser is energized and then fired, thereby directing a short, intense pulse of light into the atmosphere. As the transmitted pulse propagates through the atmosphere, light is backscattered by particles in the path of the beam and a portion of the backscattered energy is returned to the telescope receiver aligned parallel to the laser. Light collected by the telescope is focused onto the photomultiplier detector, the response of which is displayed on the oscilloscope. A permanent record of the received response is obtained by photographing the oscilloscope trace.

The constituents in the atmosphere that interact with the laser pulse and produce scattering consist mainly of air molecules and suspended particulates -- that is, tiny particles of dust, smoke, pollen and the like which range up to about a micron in size. Larger particles such as cloud droplets and ice crystals also contribute to scattering when they are present.

Atmospheric scientists are presently investigating the possibility of using lidar in a more quantitative way to determine the quantities of particulates in the atmosphere. Basically, the problem involves inverting backscatter measurements to infer the size distribution and number density of the scatterers producing the received signal. Obtaining such information is extremely difficult, however, because the scattered signal depends in a complicated way on several scatterer properties. This necessitates making certain a priori assumptions about the size distribution and indices of refraction of the particles. Fortunately, in view of recent experimental results it appears that it might be possible to obtain useful estimates of the quantities of particulates in the atmosphere by making such assumptions.

Investigations are also being conducted to determine the feasibility of using lidar as a meterological probe to detect structural features in the lower troposphere by employing the particulate scattering contribution as a structural tracer. That is, it is theorized that detectable particulate in homogeneities might be associated with pronounced variations in temperature, humidity, wind and the like. Studies at Stanford Research Institute have found that temperature inversions are often revealed by step discontinuities in lidar returns. This presumably occurs as the result of particulates being accumulated in or near the stable inversion layer. Scattering inhomogeneities have also been observed coincident with regions of high humidity and zones of wind shear. However, the information provided by lidar about any of these features is somewhat qualitative because they are only indicated indirectly by related variations in the particulate distribution. Nevertheless, this limited capability can be of use in pollution forecasting.

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APPENDIX H

AIR POLLUTION POTENTIAL ADVISORIES

(From the Weather Bureau Operations Manual)

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1. Introduction. This chapter describes the Air Pollution Potential Advisories Program. It proceeds to explain the sequence of events from preparation through dissemination of advisories as well as the terminology and operating procedures which relate to this program.

2. Definition of Air Pollution Potential. Air Pollution Potential (APP) can be defined as a measure of the inability of the atmosphere to dilute and disperse pollutants emitted into it based on the values of specific meteorological parameters (for details, see Technical Memorandum WBTM-NMC 43).

The most important parameters affecting the dilution and dispersion characteristics of the atmosphere are:

a. The mixing depth - the height to which pollutants will normally diffuse. A measure of stability.

b. The average wind speed in the mixing depth. A measure of horizontal transport of pollutants.

3. Operational Program Elements and Responsibilities.

3.1 National Meteorological Center (NMC). The National Meteorological Center prepares and issues daily the National Air Pollution Potential Advisory together with a plain language narrative and computer produced current and forecast values of the mixing depth and the average wind speed in the mixing depth (see 8. for example of NMC guidance).

3.1.1 The Advisory Format. An advisory delineating the affected area is issued when high APP is forecast within the conterminous U. S. The affected area is outlined by using well known cities as boundary points. If no area is forecast to be affected by high APP, the statement "None Today" is issued.

3.1.2 The Narrative. The plain language narrative can be added at the discretion of the NMC forecaster. The narrative can discuss the general synoptic situation as it applies to APP or it might advise of a possible APP area which does not currently meet spatial or temporal criteria for issuance of an advisory (see 4. for criteria).

3.1.3 The Mixing Depth/Average Wind Speed Data. The mixing depths and average wind speeds are prepared for "This Morning," "This Afternoon," and "Tomorrow Afternoon." The data for "This Morning" is obtained from the latest 1200Z radiosonde observations and the current minimum temperatures. The mixing depths for "This Afternoon" are derived by using the latest 1200Z radiosonde observations and the FM forecasts of maximum temperature. The average wind speed for "This Afternoon" is determined from the 12 hour FD forecasts. The data for "Tomorrow Afternoon" is derived from regression equations which relate forecasts of wind speed and temperature from the FD and FM products to mixing depth and average wind speed.

The data, produced for 72 locations where rawinsonde observations are taken daily, are transmitted in coded form. The following is the sequential arrangement and breakdown of the code:

IIiii MnMnMnW̄nW̄n MxMxMxW̄xW̄x

IIiii	The block number and station number
MnMnMn	The morning urban mixing depth for "This Morning" in decameters.
W̄nW̄n	The average wind speed in the mixing depth for "This Morning" in meters per second.
MxMxMx	The afternoon mixing depth for "This Afternoon" and "Tomorrow Afternoon" in decameters.
W̄xW̄x	The average wind speed thru the afternoon mixing depth in meters per second. (See paragraph 8.)

3.2 The Urban Air Pollution Meteorologists. In some areas Urban Air Pollution Meteorologists are assigned to local Weather Bureau Offices. These specialists provide meteorological services relating to air pollution to local pollution control action agencies and the general public. The Urban Air Pollution Meteorologist should consider issuing a local high APP advisory based on his evaluation of the following conditions:

a. A National Air Pollution Potential Advisory covers a portion of his area of forecast responsibility.

b. No national Advisory has been issued for his area of forecast responsibility but local meteorological conditions are such that high air pollution potential is likely.

3.3 Weather Bureau Forecast Offices. In offices which do not have an Urban Air Pollution Meteorologist on the staff, the forecaster on duty may issue a local high APP advisory for his area of forecast responsibility under the following conditions:

a. A National Air Pollution Potential Advisory covers a portion of his area of responsibility.

b. No National Advisory has been issued for his area of responsibility but local meteorological conditions are such that high air pollution potential is likely (see 9. for illustration of locally initiated advisory).

4. Criteria for Issuance of an Advisory.

4.1 National Meteorological Center. For initial issuance of an advisory the affected area must be at least as large as a 4° latitude-longitude square (58,000 sq. mi. - about the size of Nebraska) and the high APP must be currently in effect and forecast to persist for at least 36 hours. The spatial criterion can be reduced in size however, when very large population centers are involved (e.g., the megalopolis from Richmond to Boston which contains a population of about 37,000,000 people).

After initial issuance of an advisory, areal additions or reductions can be made without regard to size. For subsequent enlargement of an affected area, the temporal criterion is reduced to 24 hours.

When high APP ceases to exist in an advisory area or portion thereof, the advisory section of the guidance "package" will contain the statement: "End High Air Pollution Potential," and the call letters of the cities bounding the area to be deleted.

4.2 Urban Air Pollution Meteorologists and Weather Bureau Forecast Offices.

a. For issuance of an advisory there are no areal size limitations. The advisory can be for the entire area of responsibility or any part thereof.

b. For initial issuance of an advisory the high APP should be currently in effect and forecast to persist for at least 36 hours. After the initial issuance, areal additions can be made if they are currently in effect and forecast to persist for at least 24 hours.

The temporal criterion may be reduced for initial issuance of an advisory if important users such as Air Pollution Control Agencies indicate a requirement for shorter term forecasts. This may be the case in the larger cities where high pollutant concentrations may develop during high APP episodes that last only for 12 to 24 hours.

When high APP ceases to exist in a local advisory area or portion thereof a statement will be issued which describes the extent of the area no longer affected.

5. Coordination of Advisories. Urban Air Pollution Meteorologists and Weather Forecast Offices should coordinate with the National Meteorological Center either prior to issuance of an advisory or as soon after issuance as workloads permit. This coordination procedure will help NMC to define the boundary points of the National Advisory where a local and national advisory are nearly coincident and will insure consistency in the total product.

6. Dissemination and Distribution.

6.1 The NMC Guidance. The NMC guidance will be disseminated daily via Service C at 1720Z.

Receiving stations should notify local agencies having air pollution control and alerting authority of an advisory (if it affects their area of responsibility) by phone, local teletypewriter circuit or ESSA Weather Wire. These agencies can be given other meteorological advice relating to air pollution if it is requested.

After dissemination to the local control agency, Weather Bureau stations can publicize the advisory by distributing it to news media, industrial and commercial interests, and the public. This distribution may be made by ESSA Weather Wire, local teletypewriter circuit, and telephone.

6.2 Locally Initiated Advisories.

a. There is no prescribed time for issuance of a local advisory.

b. Advisories should be disseminated to agencies having local air pollution control and alerting authority (if it affects their area of responsibility) as soon as possible by telephone or local teletypewriter circuit. These agencies can be given other meteorological advice relating to air pollution if it is requested.

After dissemination to the local control agencies, Weather Bureau stations may then publicize the advisory by distributing it to local news media, industrial and commercial interests, and the public by ESSA Weather Wire, local teletypewriter, and telephone.

7. Special Services. From time to time, Urban Air Pollution Meteorologists or Weather Forecast Offices may be asked for specialized services relating to air pollution. Examples are the several requests received by offices in the Western Region for APP forecasts for burning of agricultural wastes and meteorological support for accidents involving the release of air pollutants.

For support to accident control every effort should be made to provide immediate information within the competence of the station. Otherwise, special services should be furnished only within the limits of available manpower and resources.

8. Examples of the NMC Guidance.

```
FK KWBC     181720
NATIONAL AIR POLLUTION POTENTIAL ADVISORY

CONTINUE HIGH AIR POLLUTION POTENTIAL ADVY
LIT  IND  DET  BUF  EKN  CHA
LIT                                                        ADVISORY

BEGIN HIGH AIR POLLUTION POTENTIAL ADVY
BUF  BGM  HAR  AVL  CHA
EKN  BUF

LRG HI CNTRD OVR VA EXPCD TO
BE QSTNRY NXT 36 GRS BASED                                 NARRATIVE
ONLTST UPR AIR PROGS

FKI KWBC 18 Sep 1967 1200Z
AIR POLLUTION POTENTIAL DATA


72201  14004  12605  12706  72202  10402  16008  10707  MIXING DEPTH/
72209  02099  15706  12804  72208  09709  13606  10309
72211  03304  19307  11606  72226  01507  17410  15005  AVERAGE WIND
72232  13208  13308  11807  72235  00712  14507  13604      SPEED
72240 999999* 99999* 99999* 72248  01906  17006  12604  COMPUTATIONS
72250.................CONTINUED FOR 72 STATIONS
```

*99999 Group indicates data missing

9. Example of a Locally Initiated Advisory.

ESSA.......WEATHER BUREAU AREA FORECAST CENTER NEW YORK CITY

WBO NEW YORK AIR POLLUTION METEOROLOGICAL ADVISORY NO. 1

WEDNESDAY AUGUST 16 1967 1PM EDT

A HIGH AIR POLLUTION POTENTIAL ADVISORY WAS ISSUED AT 11AM FOR THE NEW YORK METROPOLITAN AREA..SOUTHEASTERN NEW YORK ..EASTERN PENNSYLVANIA..NEW JERSEY AND CONNECTICUT BY THE WEATHER BUREAU OFFICE NEW YORK.

THIS ADVISORY WILL REMAIN IN EFFECT FOR AT LEAST 36 HOURS. A STAGNANT HIGH PRESSURE SYSTEM CENTERED OVER THE MID ATLANTIC STATES IS EXPECTED TO REMAIN ALMOST STATIONARY FOR THE NEXT 36 HOURS.

LIGHT WINDS AND POOR VENTILATION CONDITIONS PREVAILED LAST NIGHT AND THIS MORNING. THERE WILL BE SOME IMPROVEMENT IN VENTILATION CONDITIONS THIS AFTERNOON AND AGAIN THURSDAY AFTERNOON BUT A RETURN TO POOR DISPERSION CONDITIONS IS EXPECTED TONIGHT AND EARLY THURSDAY.

THE NEXT ADVISORY WILL BE ISSUED AT 11AM EDT THURSDAY AUGUST 17TH.

KUSSMAN..AIR POLLUTION METEOROLOGIST
WBO NEW YORK

APPENDIX I

Status Criteria for a High Air Pollution Alert and Warning System

A PANEL REPORT

School of Engineering and Architecture
The City College
of
The City University of New York
New York, N. Y.
December 1967

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Foreword

A system designed to protect the public against the possible adverse effects of high concentrations of contaminants in the air during periods of atmospheric stagnation must consider:

1. How to identify situations when corrective action should be taken;
2. The strategies and capabilities for control when action is necessary.

This report is concerned with the first of these considerations. The second has the nature of a technical problem requiring surveys and somewhat detailed knowledge about a particular geographic area for its solution.

The need to develop an improved "alert" and "warning" system was defined by panels of the Three-State Conference on Air Resource Management. When this concern was detected in the preliminary panel reports, representatives of the air pollution control agencies in the three-state area were invited to a meeting to discuss the problem.

Mr. Paul H. Berry, New York State; Dr. Edward Ferrand, New York City; Mr. Thomas R. Glenn, Jr., Interstate Sanitation Commission; Mr. William A. Munroe, New Jersey, and Mr. Louis J. Proulx, Jr., Connecticut, attended this meeting. They, in fact, became a planning committee which prepared an outline of topics to be considered in arriving at criteria for an "alert" and "warning" system, and a list of professional experts representing the various talents and disciplines necessary to provide a balanced discussion of the problem.

Twenty persons comprised the panel as finally assembled. Fifteen of the members were associated with air pollution control agencies in five states and the federal government, five were not directly involved with the problem of air pollution control.

The preliminary work of the panel was done by correspondence. On September 18, 19, 20 and 21, the panel met in workshop sessions at Lake Mohonk, New York. Dr. John J. Theobald served as chairman at these meetings. The individual and sub-committee reports approved at these sessions, and the minutes of the sessions are the basis for this report. The report was assembled, and then edited and revised through correspondence among the panel members.

Mr. Robert H. Beman, Chief, Environmental Health Laboratory, Philadelphia, Department of Health, was not present at the workshop meetings. However, his report on experience in Philadelphia (with suggestions on "alert" and "warning" levels and procedures) influenced the panel's discussions.

The terms "alert", "warning" and "emergency" are used reluctantly in this report. Any word in common parlance will have different connotations to various people. Some time was spent by the panel in an attempt to select other words or phrases. However, it was decided that, at this time, terminology should not be allowed to delay the development of criteria.

The panel tried to be completely objective in seeking to establish these criteria. Naturally, the members were influenced by their experience in the five states represented. However, insofar as possible, local problems were not permitted to intrude on the discussions.

The time, effort and cooperation of the panel participants is greatly appreciated.

Richard G. Coulter
Conference Coordinator

Panel Participants

Participant	**Affiliation**
Anderson, David M., Ph.D.	Assistant Manager, Environmental Quality Control, Bethlehem Steel Corp.
Ayres, Stephen M., M.D.	Cardio-pulmonary Laboratory, St. Vincent's Hospital.
Berry, Paul H.	Director, Bureau Air Quality Surveillance, N. Y. State Dept. of Health.
Chalker, William R.	Senior Waste Consultant, E. I. duPont de Nemours Co. Member, Delaware Water and Air Resources Commission.
Chaves, Aaron D., M.D.	Director, Tuberculosis Bureau, New York City Dept. of Health.
Coulter, Richard G.	Professor of Civil Engineering, The City College of New York.
Cowherd, George T., Jr.	Asst. Chief Engineer, Interstate Sanitation Commission.
Hambright, James K.	Chief, Air Resource Management and Research, Pennsylvania Department of Health.
Jacobs, Harold L.	Vice Chairman, Delaware Water and Air Resources Commission.
Landau, Emanuel, Ph.D.	Statistical Adviser, Office of the Director, National Center for Air Pollution Control.
McCormick, Robert A.	Chief, Meteorology Program, National Center for Air Pollution Control.
Munroe, William A.	Chief, Air Sanitation Program, New Jersey Dept. of Health.
Proulx, Louis J., Jr.	Chief, Air Pollution Control Section, Connecticut Dept. Health.
Rihm, Alexander, Jr.	Assistant Commissioner, New York State Department of Health.
Risman, Arnold	Associate Engineer, New York State Department of Health.
Simon, Conrad	Senior Meteorologist, New York City Department of Air Pollution Control.
Sussman, Victor H.	Director, Division of Air Pollution Control, Pennsylvania Dept. of Health.
Theobald, John J., Ph.D.	Executive Vice-President, New York Institute of Technology.
Wilburn, James T.	Director, Air Pollution Control Division, Delaware Water and Air Resources Commission.
Yunghans, Roland S.	Research Scientist, Air Pollution Control Program, N. J. Department of Health.

Summary

The serious air pollution episodes occur during periods of atmospheric stagnation, when meteorological conditions reduce normal ventilation and diffusion. Under these conditions, the concentrations of contaminants in the atmosphere can reach levels that are a threat to health.

Continuous air monitoring stations record the concentrations of a variety of substances. However, for the purpose of initiating prompt remedial action when a potential for high air pollution exists, it is essential that a limited number of indices be examined. Taken together, the concentrations of carbon monoxide and sulfur dioxide and soiling index—the amount of matter suspended in the atmosphere—roughly indicate the intensity of atmospheric contamination. In addition, they have been recorded for some time allowing evaluation of previous experiences, and medical researchers have used them as indices in studying the effects of air pollution on health.

In order to implement an air pollution "alert" and "warning" system, the full cooperation of the United States Weather Bureau is necessary. Forecasts of conditions leading to high air pollution potential and the duration of these weather conditions are essential to air pollution control actions.

An area complex having common topographic and meteorological characteristics (and, in which individual sources of pollution emissions cannot readily be discerned) should be treated as a single unit regardless of the political jurisdictions involved. An essential first step for a coordinated control program utilizing these criteria will be the delineation of these areas.

STATUS	CONDITIONS
Forecast	An advisory by the Weather Bureau that a high air pollution potential will exist for the next thirty-six hours.
Alert	Advisory that adverse weather conditions will continue for twelve hours plus Sulfur dioxide = 2.0 ppm-hrs and soiling index = 25 RUD-hrs/1000 ft. in any consecutive 6 hours of the last 12 hours

	or	Carbon monoxide = 180 ppm-hrs in any consecutive 6 hrs. of the last 12 hours
	or	Sulfur dioxide = 6.0 ppm-hrs and dosage is increasing and soiling index = 100 RUD-hrs/1000 ft. in the last 24 hours
Warning		Advisory that adverse weather conditions will continue for twelve hours **plus** Sulfur dioxide = 3.0 ppm-hrs and soiling index = 25 RUD-hrs/1000 ft. in any consecutive 6 hours of the last 12 hours
	or	Carbon monoxide = 300 ppm-hrs in any consecutive 6 hrs. of the last 12 hrs.
	or	Sulfur dioxide = 9.0 ppm-hrs and dosage is increasing and soiling index = 100 RUD-hrs/1000 ft. in the last 24 hours
Emergency		Advisory that adverse weather conditions will continue for twelve hours **plus** Sulfur dioxide = 15.0 ppm-hrs and soiling index = 200 RUD-hrs/1000 ft. in the last 24 hours
Termination		Advisory that adverse weather conditions have ended.

The Panel Report

Introduction and a Limitation

The status criteria for an air pollution alert and warning system proposed herein should in no way be confused with ambient air quality standards designed for the general management of the air resource. These criteria have been established for the purpose of identifying situations where meteorological conditions and the emissions of contaminants to the atmosphere are such that increased air pollution may become an immediate menace to the public health unless remedial actions are instituted. This is not to imply that lower levels of atmospheric contamination may not have an effect on health. However, a system designed to cope with unusual situations should not be confused with one designed to control customary levels of contaminants in the atmosphere. It is entirely possible that at some places contaminant dosages incorporated in these criteria are equalled, or exceeded, at rather frequent intervals. Such places must be the target of control programs designed to improve ambient air quality per se. In truth, it is hoped that ongoing programs to improve ambient air quality will, in time, eliminate the need for implementing emergency procedures. In the meantime, the alert and warning system criteria should not be used in an attempt to control these "normal" levels of contamination (1).

Basic Considerations in the Predication of Criteria

Incidents of high concentrations of air pollution usually are not the result of suddenly increased emissions to the atmosphere. In local areas a fire, an explosion or other accident may produce sudden increases of air pollution. Such incidents are not in the purview of these criteria. If toxic materials are involved, normal police procedures may be expected to cause evacuation of people from the danger area.

High air pollution incidents of greatest concern are those that occur when meteorological conditions reduce the ventilation or diffusion of contaminants normally present over any area. In these circumstances emission rates may remain fairly constant, but a logarithmic build-up of contaminant concentrations can occur.

The portent of an impending period of high air pollution potential is the development of meteorological conditions leading to light winds and atmospheric stagnation. The severity of the incident will depend upon the magnitude of the concentrations of contaminants and the duration of exposure.

Control agencies are currently operating continuous air sampling stations and have plans for installing additional stations. Within the next year, it is anticipated that ten stations will be operating in New York City, twenty in New York State, twenty-two in New Jersey, four in Pennsylvania, three in Connecticut and two in Delaware. Each of these stations will be equipped to measure the concentrations of a variety of contaminants in the atmosphere. However, for the purpose of initiating prompt remedial action when a potential for high air pollution exists, it is essential that a limited number of indices be examined to determine the quality of the ambient air.

These criteria propose to use sulfur dioxide, carbon monoxide and soiling index as the indices of air pollution for the alert and warning system.

This selection was tempered by the following considerations:

1. Existing and planned stations are equipped to make these measurements and, in many cases, will telemeter the observations to a central control headquarter.

2. The New York-New Jersey Cooperative Committee on Interstate Air Pollution (2) has been using these indices in its Regional Air Pollution Warning System. Therefore, it is possible to evaluate the effect of the proposed criteria in the light of previous experience.

3. Since these indices of air pollution have been reported for some time, medical researchers have generally attempted to correlate health effects with one or more of these parameters.

4. Sulfur dioxide and carbon monoxide are in themselves toxicants with known physiological effects on man (3)(4)(5). These indices, in combination with soiling index, offer a parameter that roughly indicates the intensity of total emissions being made to the atmosphere and, to some extent, the dominant sources during the sampling period.

Sulfur dioxide emissions largely result from the combustion of fuels for the production of heat and power.

Carbon monoxide is emitted in significant amounts in the exhaust from internal combustion engines.

The fumes and aerosols that produce the soiling index are contributed by many sources—operation of motor vehicles, industrial pocesses, incineration of refuse and the combustion of fuels.

In every case, it may be anticipated that emission of one of the indicator materials will be accompanied by various amounts of other substances. Oxides of nitrogen, carbon dioxide, hydrocarbons, other sulfides, organics and inorganics are also released by the processes that produce sulfur dioxide, carbon monoxide and soiling index. However, until experience demonstrates that other substances are more significant or sensitive indicators, the sulfur dioxide-carbon monoxide-soiling index parameter is recommended for gauging total pollution in the atmosphere. A control program to preserve ambient air quality should consider the degree of control necessary for all types of emissions, and not be specifically concerned with those indices used to evaluate overall pollution levels.

The Criteria

1. *Status–"FORECAST"*–an internal watch shall be actuated by a United States Weather Bureau advisory that a high air pollution potential will exist for the next thirty-six hours.

2. *Status–"ALERT"*–At the initiation of, and periodically during, a "Forecast" period, air quality information for the immediately preceding twenty-four-hour period shall be reviewed. If for any consecutive six-hour period during the last twelve hours, the sulfur dioxide dosage is equal to or exceeds 2.0 parts per million-hours, *and* soiling index is equal to or exceeds 25 RUD-hours/1000 lin. ft.,

OR

if for any consecutive six hours in the immediately preceding twelve hours, the carbon monoxide dosage is equal to or exceeds 180 parts per million-hours,

OR

if the sulfur dioxide dosage for the immediately preceding twenty-four-hour period is equal to or exceeds 6.0 parts per million-hours, *and* the dosage is increasing *and* the soiling index is equal to or exceeds 100 RUD-hours/1000 lin. ft.

AND

adverse meteorologic conditions are predicted for at least an additional twelve hours:

"ALERT" status has been reached.

3. *Status–"WARNING"*–If during an "alert" period, for any consecutive six hour period during the immediately preceding twelve hours, the sulfur dioxide dosage is equal to or exceeds 3.0 parts per million-hours, *and* the soiling index is equal to or exceeds 25 RUD-hours/1000 lin. ft.,

OR

if for any consecutive six hours in the immediately preceding twelve hours, the carbon monoxide dosage is equal to or exceeds 300 parts per million hours,

OR

if the sulfur dioxide dosage for the immediately preceding twenty-four-hour period is equal to or exceeds 9.0 parts per million-hours, *and* the

dosage is increasing *and* the soiling index is equal to or exceeds 100 RUD-hours/1000 lin. ft.,

AND

adverse meteorologic conditions are predicted for at least an additional twelve hours:

"WARNING" status has been reached.

4. Status—"EMERGENCY"—If during a "warning" period, in any consecutive twenty-four-hour period the sulfur dioxide dosage is equal to or exceeds fifteen parts per million-hours, *and* the soiling index is equal to or exceeds 200 RUD-hours/1000 lin. ft.,

AND

adverse meteorologic conditions are predicted for at least an additional twelve hours:

"EMERGENCY" status has been reached.

5. Status—"TERMINATION"—Once declared, any status reached by application of these criteria shall remain in force until the high air pollution potential advisory is ended.

Health Considerations

Present knowledge regarding the effects of air pollution on health is imperfect (6). There are many substances in the atmosphere; some are naturally present, others (pollutants) are added (or, increased in amount) by man's activities. Most of these substances can be identified, and their source and presence explained.

The effects of certain toxicants on human health is known. However, the reaction of particular individuals (including those with respiratory ailments) to these materials alone, or in combination, is markedly dfferent (7).

Synergistic effects have been demonstrated between sulfur dioxide and sulfuric acid droplets and other particulates (8)(9). The catalytic action of metallic materials in the conversion of sulfur dioxide to sulfur trioxide has also been demonstrated (4). Nitrogen dioxide has been indicted as the energy receptor in the formation of photochemical smog with the associated production of eye irritants and particulates (10). Under these circumstances, it is understandable that epidemiological studies of severe air pollution episodes are not entirely conclusive with regard to the quantitative dosages of contaminants causing clinical effects. However, there is little question that increased morbidity and mortality does occur during periods of greatly increased concentrations of air contaminants (11)(12).

Recognizing that health effects do occur, even though the multifactorial causes cannot be completely discerned, these status criteria have been based on currently available evidence (4)(5)(12)(13). From a medical point of view, it may be premature to say that this evidence is conclusive. Therefore, it should be recognized that continuous review; and, perhaps, change of criteria will be necessary as new evidence is presented.

Carbon monoxide combines with the blood's hemoglobin to form carboxyhemoglobin. As in most chemical reactions, time, temperature and concentration are factors in this reaction. Within the human body, time and atmospheric concentration of carbon monoxide determine the equilibrium condition obtained. An individual exposed to an atmosphere containing carbon monoxide will come into equilibrium with his environment. The carboxyhemoglobin concentration in his blood will increase, or decrease, with changing concentrations of carbon monoxide in the atmosphere. In these criteria, "alert" and "warning" status recognize levels of blood carboxyhemoglobin at which measurable effects are found in some individuals (5).

Sulfur dioxide (alone, and in association with particulates) is recognized as a toxicant. Possibly more attention has been devoted to sulfur dioxide in the atmosphere than to any other contaminant. Recent surveys of the available literature appear to indicate that there is a range of concentrations and exposure times in which increasingly significant health effects have been reported to occur (4)(13). The "alert" status, herein proposed, is at the borderline between suspected and possibly significant effects. The "emergency" status has been placed at the borderline of time-concentration above which available evidence indicates clinical effects may be expected to be reported.

The use of a soiling index for continuously evaluating the status of suspended particulates during high air pollution potential situations is necessary since this is the only currently available method for which sufficient data are available to enable establishment of criteria. However, in synergistic effects probably only respirable particles capable of adsorbing gases are significant. Further research is indicated.

The Units of Measurement

These criteria incorporate the concept of dosage as the measure of exposure to contaminants. Dosage is calculated as the area under the curve of concentration versus time.

During inversion periods, the concentrations of contaminants fluctuate with time. These fluctuations result from the operation of a complex set of variants; and are influenced by momentary emission rates, rate of decay or reaction of the contaminants, absorption, adsorption, subsidence of particulates, turbulence, diffusion and change of inversion altitude.

Examination of the variation of pollutant indices recorded in New Jersey during previous episodes of high air pollution potential indicate that normal diurnal fluctuation of contaminant concentrations can be distributed in these periods (14). Plotting periodic average concentrations during a stagnation period may not indicate increase in overall exposure; whereas, plotting dosage will do so. Periodic plotting of cumulative dosage during periods of high air pollution potential indicates the trend of pollutant exposure even though the pollutant concentration may follow a diurnal pattern (15).

Maximum sulfur dioxide dosages vary exponentially with the duration time of sampling. Linearity may be observed when a logarithmic plot is made of two-hour, four-hour, six-hour and twenty-four-hour exposures (14). Generally, maxima or near maxima when observed during the first twelve hours of a day seem to give a good indication of that day's pollution potential. Two, four or six-hour maxima or near maxima dosages when actually observed during the first or second six hour periods of the day may be used to predict the approximate twenty-four-hour dose (14).

Considering the diurnal trend of fluctuations in contaminant concentrations, the possible variation in meteorological conditions, the need for weather forecasts and the number of computations involved; a six-hour dosage has been selected as the standard for status determination.

Automated equipment presently installed for the measurement of soiling index utilizes light reflectance rather than transmittance in evaluating stain density. The primary measurement being made is in RUD units with conversion to COH units for reporting purposes (16). It appears more desirable to have data reported directly in the unit of measurement. For the purpose of comparisons, it will be necessary to convert presently available data to the RUD scale. However, this appears more logical than converting all future data to the COH scale. At sampling stations in New Jersey, a log-log plot of RUD vs. COH yields a straight line, so direct conversion appears possible. Since these measurements are affected by particle shape and color, a station-by-station correlation may be desirable with, if necessary, a conversion curve prepared for each one.

The sampling and analytical procedures employed are to be consistent with obtaining accurate results which are representative of the conditions being evaluated. The following sampling and analytical techniques are to be used directly, or as reference standards against which other methods are to be calibrated.

a) Carbon Monoxide—continuous measurement, by use of non-dispersive infrared technique, reported in parts per million.

b) Soiling index—measurement of paper tape light reflectance at one-hour intervals with a sampling rate of 0.5 cubic feet per minute. The one-hour sampling period, at a sampling rate of 0.5 cfm, was selected since shorter sampling periods would not materially add to the needed information, and since hourly review of data is anticipated. A standard black must be adopted for this measurement. Report in RUD units.

c) Sulfur dioxide—continuous measurement by the West-Gaeke procedure, chemically corrected for oxides of nitrogen, reported in parts per million.

Complete standardization of sampling and analytical techniques is a desirable goal. Budgetary, and other considerations, will probably delay the attainment of this goal for some time. In selecting sampling sites, care should be taken to assure that local sources have minimal effect upon sampling results. Standardization of sampling point elevation is desirable, and a fifteen foot height was discussed. However, practical problems of site location require too much flexibility to enable standardization at this time.

Recommended Collateral Sampling

These criteria and the pollution indices selected are in part, based on the previous experience of the panel participants in the areas of their immediate concern. Legislation restricting the sulfur content of fuels and repressive measures directed toward automobile exhaust emissions may, in time, drastically change the syndetic relationship of the contaminants present in the atmosphere over any area.

Oxidant concentrations and dosages have demonstrable effects on man and vegetation. It is not possible to predict how present contaminant patterns will change. However, both "London (reducing) Smog" and "Los Angeles (oxidizing) Smog" have been observed in the area represented on this panel. Decreased sulfur oxide emissions should reduce the frequency potential for formation of London Smogs. It is possible that, in these areas, oxidants in the atmosphere may, in time, become relatively more important than they have been in the past.

While the presence of nitrogen oxides and hydrocarbons are precursors of increased oxidant concentration, it is considered that monitoring of total oxidants will best indicate changing conditions for assessing the need for changes in the criteria indices.

Total oxidants (as here defined) include any substance giving a positive reaction using the neutral potassium iodide procedure corrected for sulfur dioxide (but not corrected for nitrogen oxides) reported in parts per million.

Particle concentration, size and respirable mass and/or surface area may be more important in correlating health effects than soiling index. However, none of these can be easily correlated, if at all, with soiling index. Some instrumentation is available and under development for particle count and respirable mass measurement. It is recommended that investigations be conducted on the practicality of eventually substituting one, or more, of these measurements for soiling index.

Recommendations Concerning Implementation

In the implementation of this system primary consideration is given to weather forecasts which can materially affect air contaminant concentrations. The predicted duration of high air pollution potential is a major consideration, as it can have an appreciable effect on the need for air pollution control actions.

The full cooperation of the United States Weather Bureau is necessary for satisfactory implementation of this system. It is recommended that all agencies participating in an Air Pollution Warning System utilize the services of the regional office designated by the United States Weather Bureau for information on high Air Pollution Potential Advisories. These advisories to be the same as the thirty-six-hour forecast, relating to a minimum area coverage of 70,000 square miles, now originating at the National Meteorological Center. For a smaller area, a thirty-six-hour forecast may be originated by an office closer to the local area.

A request should be made to the United States Weather Bureau to provide twenty-four-hour coverage at the central office by a forecaster capable of making pollution potential forecasts during periods when a substantial portion of the participating region lies in the high pollution potential area. A further request should be made to the United States Weather Bureau to provide information on an hourly basis, if necessary, and new or upgraded twelve-hour forecasts at intervals of no more than six hours during such periods.

Whenever the forecast area covers a small portion of the participating region, the agencies involved should voluntarily consult the air pollution meteorologist assigned to their area and designated for this purpose by the Weather Bureau.

Upon receipt of an advisory from the United States Weather Bureau, the coordinating agency shall contact the participating agencies individually giving information on the area of forecast coverage, and other pertinent information.

During a major alert condition, all participating agencies should bear the responsibility for initiating calls to the coordinating agency for the purpose of receiving updated information. Each participant shall be advised when the high pollution potential forecast has been terminated in his area.

Existing stations and planned new installations are rapidly forming the monitoring networks that will sample contaminant concentrations during periods of high air pollution potential. Each agency has plans for additional installations when funds become available. In time, experience will indicate which stations yield the most significant data during a stagnation period. At a later date, it may become desirable to designate certain stations as forming the control network.

When a serious episode develops, effective comprehensive control action will require that geographic areas to be treated as a unit have been designated prior to the episode.

It is recommended that participating agencies acting in concert shall, as quickly as possible, delineate the boundaries of those areas to be considered as a single "complex". A "complex" will embrace an area having common meteorological and topographical characteristics. Contaminant emissions within the "complex" will come from a multiplicity of scattered sources so intermingled and distributed that particular sources cannot be readily discerned. For the purpose of the alert and warning system, each such "complex" shall be considered as a separate entity regardless of the political jurisdictions involved.

When said "complexes" have been designated, one or more sampling stations may be located within the boundaries of each one. When one sampling station within a "complex" reports contaminant levels at or above an alert status, the entire area in the "complex" should be declared as at the appropriate status unless, in the judgment of the responsible authority, there is good reason to suspect that the readings from this station are not representative of actual conditions at that time.

Footnotes

(1) "Panel Report on Controls and Emergency Procedures", *Proceedings Three-State Conference on Air Resources Management*. The City College (1967).

(2) The New York-New Jersey Cooperative Committee on Interstate Air Pollution was established in 1959. The Committee is composed of representatives from the states of New York and New Jersey, the Interstate Sanitation Commission and New York City. The Interstate Sanitation Commission has been designated as the coordinating agency for the presently existing Regional Air Pollution Warning System.

(3) R. I. Larsen. "Air Pollution from Motor Vehicles", N. Y. Academy of Sciences. April 6, 1966.

(4) "Air Quality Criteria for Sulfur Oxides", United States Department of Health, Education and Welfare. Public Health Service. National Center for Air Pollution Control. March 1967.

(5) "Carbon Monoxide" from "Documentation of Threshold Limit Values", American Conference of Governmental Industrial Hygienists, Cincinnati (1966).

(6) "Panel Report. Health Effects", *Proceedings Three-State Conference on Air Resource Management*. The City College (1967).

(7) Spicer, W. S., "The Complexity of Relationship Between Air Pollution and Respiratory Health". Proceedings. National Conference on Air Pollution, December 1962. *PHS Publication No. 1022*.

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APPENDIX J

EXAMPLE EMERGENCY CONTROL ACTIONS *

Section 1. FIRST ALERT LEVEL

Part A. GENERAL

1. Any person responsible for the operation of a source of atmospheric contamination listed in Part B of this Section shall take all required control actions for this Alert Level.
2. There shall be no open burning by any persons of tree waste, vegetation, refuse, or debris in any form.
3. The use of incinerators for the disposal of any form of solid waste shall be limited to the hours between 12:00 noon and 4:00 p.m.
4. Persons operating fuel-buring equipment which requires boiler lancing or soot blowing shall perform such operations only between the hours of 12:00 noon and 4:00 p.m.

Part B. SOURCE CURTAILMENT

Source of Air Contamination	Air Pollution Alert
1. Coal or oil-fired electric power generating facilities.	a. Substantial reduction by utilization of fuels having low ash and sulfur content. b. Maximum utilization of mid-day (12:00 noon to 4:00 p.m.) atmospheric turbulence for boiler lancing and soot blowing. c. Substantial reduction by diverting electric power generation to facilities outside of Alert Area.
2. Coal and oil-fired process steam generating facilities having a capacity to burn in excess of four tons of coal per hour or 600 gallons of fuel oil per hour.	a. Substantial reduction by utilization of fuels having low ash and sulfur content. b. Maximum utilization of mid-day (12:00 noon to 4:00 p.m.) atmospheric turbulence for boiler lancing and soot blowing. c. Substantial reduction of steam load demands consistent with continuing plant operations.

*These are actions being considered by the State of New Jersey at the time of writing; courtesy of Mr. William Munroe, Director, NJDAPC.

3. Manufacturing industries of the following classifications which employ more than twenty (20) employees at any one location: Primary Metals Industries Petroleum Refining and Related Industries Chemical and Allied Products Industries Paper and Allied Products Industries Glass, Clay and Concrete Products Industries	a. Substantial reduction of air contaminants from manufacturing operations by curtailing, postponing, or deferring production and all operations. b. Maximum reduction by deferring trade waste disposal operations which emit solid particles, gas vapors or malodorous substance. c. Maximum reduction of head load demands for processing. d. Maximum utilization of mid-day (12:00 to 4:00 p.m.) atmospheric turbulence for boiler lancing or soot blowing.

Section 2. SECOND ALERT LEVEL

Part A. GENERAL

1. Any person responsible for the operation of a source of atmospheric contamination listed in Part B of this Section shall take all required control actions for this Alert Level.

2. There shall be no open burning by any persons of tree waste, vegetation, refuse, or debris in any form.

3. The use of incinerators for the disposal of any form of solid waste or liquid waste shall be prohibited.

4. Persons operating fuel-burning equipment which requires boiler lancing or soot blowing shall perform such operations only between the hours of 12:00 noon and 4:00 p.m.

Part B. SOURCE CURTAILMENT

Source of Air Contamination	Air Pollution Alert
1. Coal or oil-fired electric power generating facilities.	a. Maximum reduction by utilization of fuels having lowest ash and sulfur content. b. Maximum utilization of mid-day (12:00 noon to 4:00 p.m.) atmospheric turbulence for boiler lancing and soot blowing. c. Maximum reduction by diverting electric power generation to facilities outside of Warning Area.

2. Coal and oil-fired process steam generating facilities having a capacity to burn in excess of four tons of coal per hour or 600 gallons of fuel oil per hour.	a. Maximum reduction by utilization of fuels having the lowest available ash and sulfur content. b. Maximum utilization of mid-day (12:00 noon to 4:00 p.m.) atmospheric turbulence for boiler lancing and soot blowing. c. Making ready for use a plan of action to be taken if an emergency develops.
3. Manufacturing industries of the following classifications which employ more than twenty (20) employees at any one location: Primary Metals Industries Petroleum Refining and Related Industries Chemical and Allied Products Industries Papernand Allied Products Industries Glass, Clay and Concrete Products Industries	a. Maximum reduction of air contaminants from manufacturing operations by, if necessary, assuming reasonable economic hardship by postponing production and allied operation. b. Maximum reduction by deferring trade waste disposal operations which emit solid particles, gases, vapors or malodorous substances. c. Maximum reduction of heat load demands for processing. d. Maximum utilization of mid-day (12:00 noon to 4:00 p.m.) atmospheric turbulence for boiler lancing or soot blowing.

Section 3. THIRD ALERT LEVEL

Part A. GENERAL

1. Any person responsible for the operation of a source of atmospheric contamination listed in Part B of this Section shall take all required control actions for this Alert Level, and shall put standby plans into effect.

2. There shall be no open burning by any persons of tree waste, vegetation, refuse, or debris in any form.

3. The use of incinerators for the disposal of any form of solid or liquid waste shall be prohibited.

4. All places of employment described below shall immediately cease operations:

a. Mining and quarrying of non-metallic minerals.

b. All construction work except that which must proceed to avoid emergent physical harm.

c. All manufacturing establishments except those required by Code Chapter XII to have in force an air pollution emergency plan.

d. Wholesale trade establishments; i.e., places of business primarily engaged in selling merchandise to retailers, to industrial, commercial, institutional or professional users, or to other wholesalers, or acting as agents in buying merchandise for or selling merchandise to such persons or companies.

e. All offices of local, county, and State government including authorities, joint meetings, and other public bodies excepting such agencies which are determined by the chief administrative officer of local, county or State government, authorities, joint meetings and other public bodies to be vital for public safety and welfare and the enforcement of the provisions of this order.

f. All retail trade establishments except pharmacies and stores primarily engaged in the sale of food.

g. Banks, redit agencies other than banks, securities and commodities brokers, dealers, exchanges and services; offices of insurance carriers, agents and brokers, real estate offices.

h. Wholesale and retail laundries, laundry services and cleaning and dyeing establishments; photographic studios; beauty shops, baber shops; shoe repair shops.

i. Advertising offices; consumer credit reporting, adjustment and collection agencies; duplicating, addressing, blueprinting; photocopying, mailing, mailing list and stenographic services; equipment rental services; commercial testing laboratories.

j. Automobile repair, automobile services, garages.

k. Establishments rendering amusement and recreation services including motion picture theatres.

l. Elementary and secondary schools, colleges, universities, professional schools, junior colleges, vocational schools, and public and private libraries.

5. All commercial and manufacturing establishments not included in items No. 1 or 4 of this order will institute such actions as will result in maximum reduction of air contaminants from their operations by ceasing, curtailing, or postponing operations which emit air contaminants, to the extent possible without causing injury to persons or damage to equipment.

6. The use of motor vehicles is prohibited except in emergencies with the approval of local or state police.

Part B. SOURCE CURTAILMENT

Source of Air Contamination	Air Pollution Emergency
1. Coal or oil-fired electric power generating facilities.	a. Maximum reduction by utilization of fuels having lowest ash and sulfur content. b. Maxiumu utilization of mid-day (12:00 noon to 4:00p.m.) atmospheric turbulence for boiler lancing and soot blowing. c. Maximum reduction by diverting electric power generation to facilities outside of Emergency Area.
2. Coal and oil-fired process steam generating facilities having a capacity to burn in excess of four tons of coal per hour or 600 gallons of fuel oil per hour.	a. Maximum reduction by reducing heat and steam demands to absolute necessities consistent with preventing equipment damage. b. Maximum utilization of mid-day (12:00 noon to 4:00 p.m.) atmospheric turbulence for boiler lancing and soot blowing. c. Taking the action called for in the emergency plan.
3. Manufacturing industries of the following classifications which employ more than twenty (20) employees at any one location: Primary Metals Industries Petroleum Refining and Related Industries Chemical and Allied Products Industries Paper and Allied Products Industries Glass, Clay and Concrete Products Industries	a. Elimination of air contaminants from manufacturing operations by ceasing, curtailing, postponing or deferring production and allied operations to the extent possible without causing injury to persons or damage to equipment. b. Elimination of air contaminants from trade waste disposal processes which emit solid particles, gases, vapors or malodorous substances. c. Maximum reduction of heat load demands for processing. d. Maximum utilization of mid-day (12:00 noon to 4:00 p.m.) atmospheric turbulence for boiler lancing or soot blowing.